The Journal of Bone and Joint Surgery

The Official Publication of

The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association

JANUARY 1952

American Volume
Vol. 34-A, No. 1

8 THE FENWAY, BOSTON 15, MASSACHUSETTS, U. S. A.
BRITISH OFFICE:
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The Journal of Bone and Joint Surgery

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The Journal of Bone and Joint Surgery (American Volume) is issued quarterly—in January, April, July, and October. The 1952 subscription price, payable in advance, is $10.00. Single copies $2.50.

The Journal of Bone and Joint Surgery, entered as second-class matter August 1, 1921, at the Post Office, Boston, Mass., under the act of March 3, 1879. Editorial and business offices, 8 The Fenway, Boston, Mass. Accepted at the special rate of postage provided for in the act of February 28, 1925, Paragraph 4, Section 412, Postal Laws and Regulations; authorized April 21, 1932. Additional entry at Concord, New Hampshire, authorized June 10, 1947.

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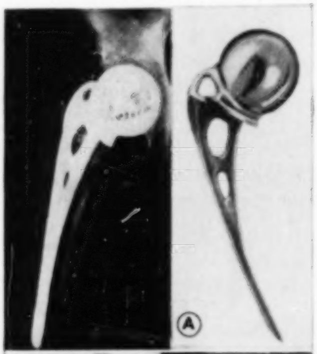

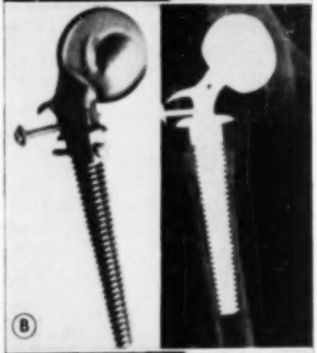

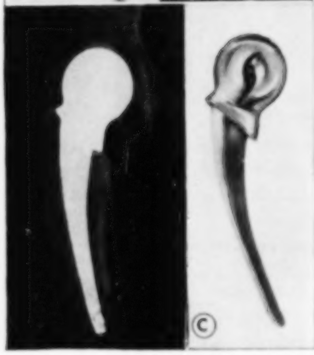

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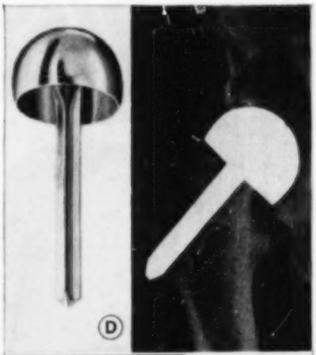

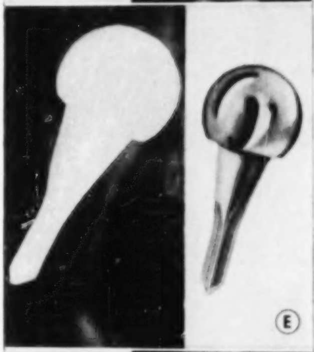

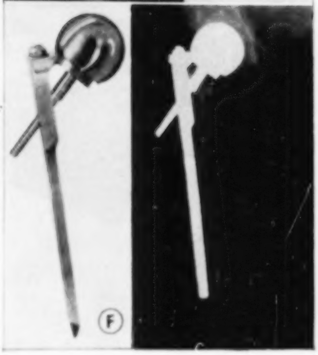

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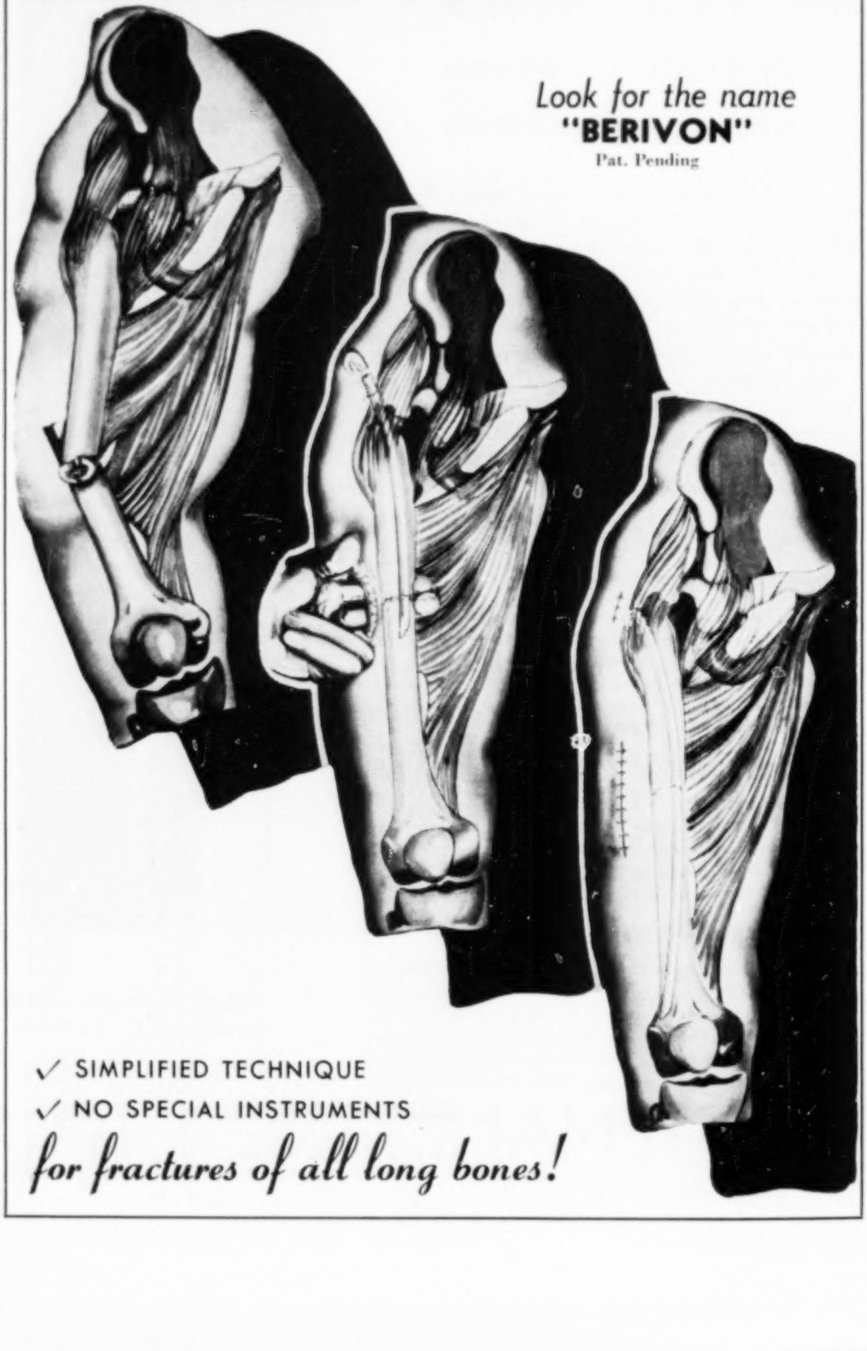

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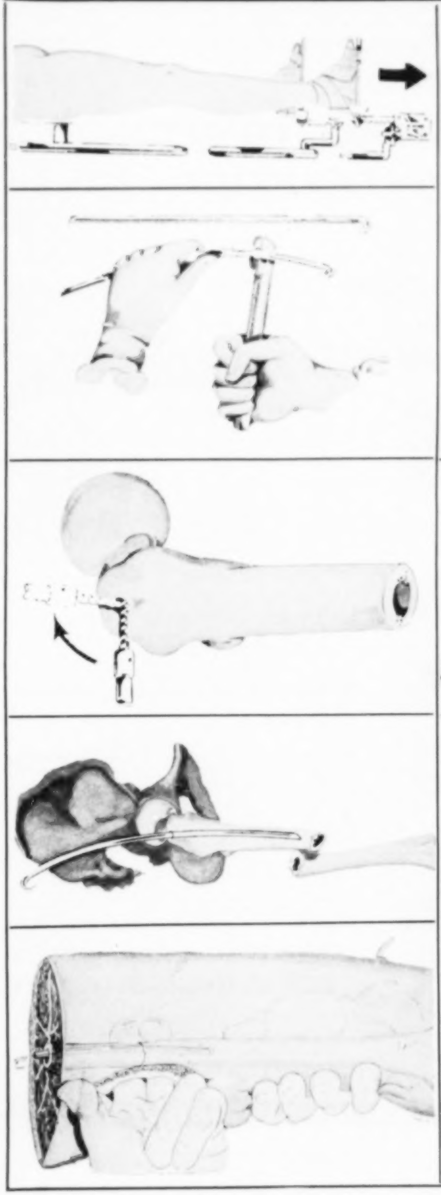

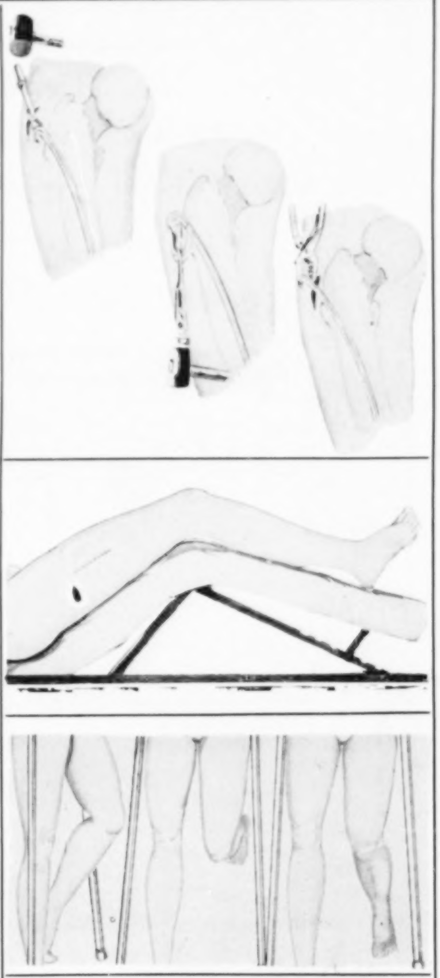

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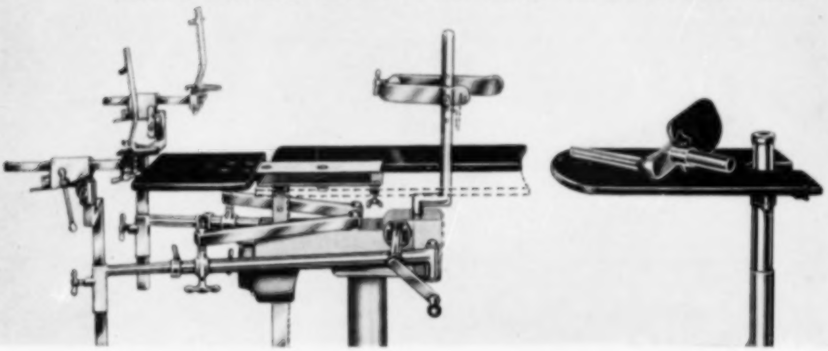

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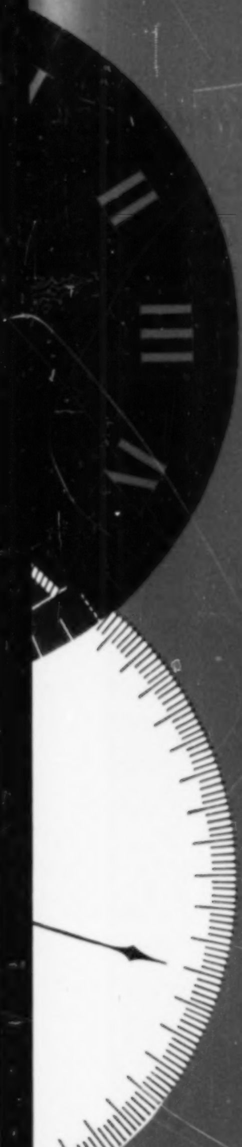

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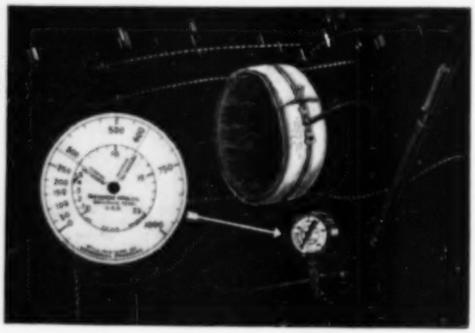

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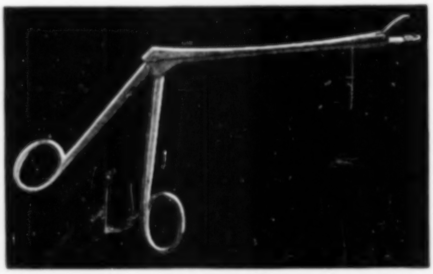

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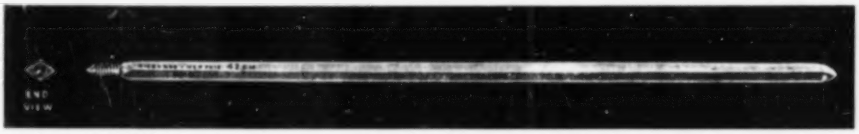
THE **NEW** HANSEN-STREET INTRAMEDULLARY NAIL FOR THE FEMUR

SMO STAINLESS STEEL



Lengths: 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52 Cms.	**$10.00**
Diameters: 11mm. × 8mm. for 95% of cases, 9mm. × 7mm. for smaller cases.	

This nail, with the new pointed and threaded head, is just what has been desired for the **Simplest, Easiest** and **Fastest** insertion of intramedullary nails. Insertion by retrograde is now accomplished with no difficulty, in that you are using the nail as its own guide, coming thru the trochanter with no shattering effect, merely by using your regular mallet of bronze or aluminum. After it has come thru the trochanter, an incision is made and the **New Extractor-Driver** is screwed on the head of the nail. Using the handle as holder for support, the nail is then driven back into the distal fragment, after approximation. Rotation is not possible with this type of nail.

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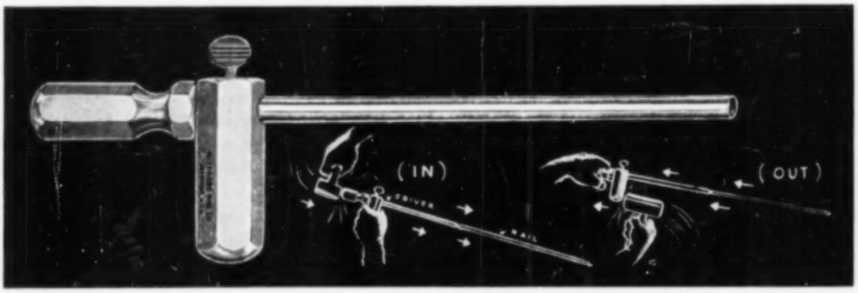

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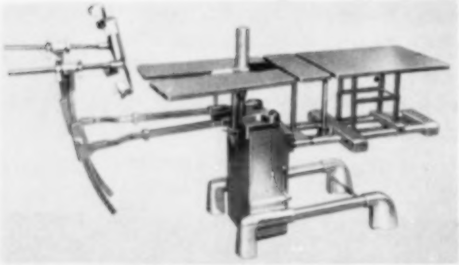

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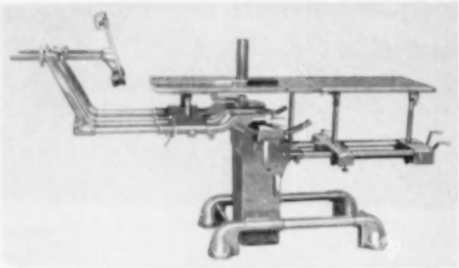

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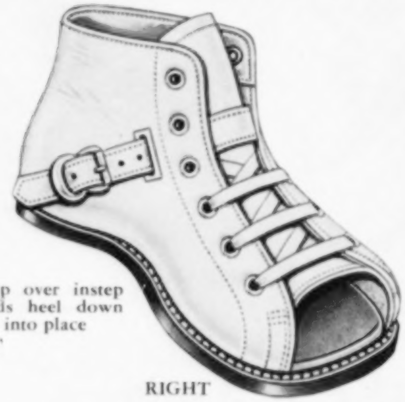
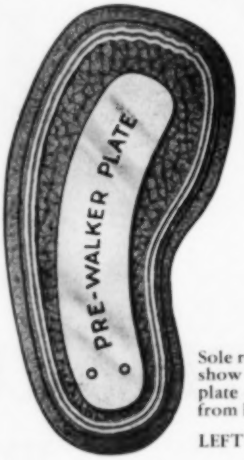
The Pre-Walker Surgical shoe with OPEN TOE, the matching shoe where only one foot requires the Pre-Walker Club Foot shoe.



Strap over instep holds heel down into place

RIGHT



Sole removed to show flat steel plate extending from heel to toe

LEFT

THIS Pre-Walker Club Foot shoe is designed and made for infants to be worn until the child can stand or walk alone. The "PRE-WALKER" Club Foot shoe can be worn by the infant at all times, and also can be kept on while the child is in bed. Its function is to keep the foot in the exact position that the physician has obtained.

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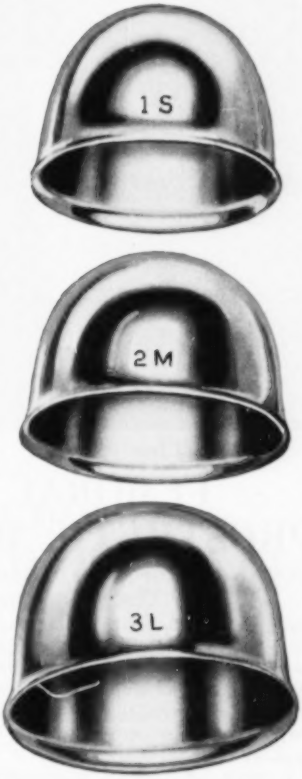

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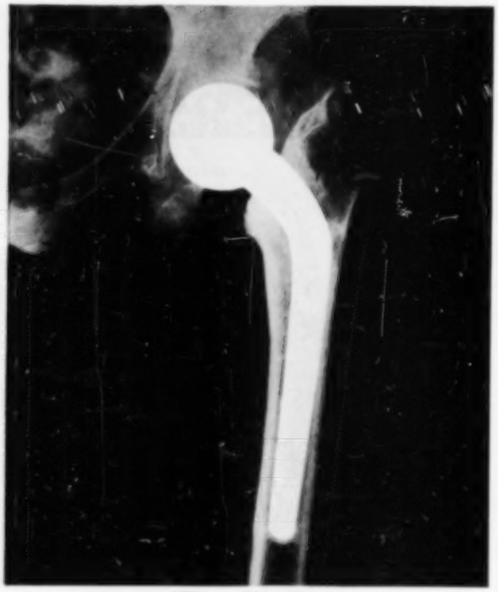

The Eicher
FEMORAL PROSTHETIC HEAD

(X-Ray taken after patient has been walking 10 months)

The Eicher Femoral Prosthetic Head is a complete one-piece replacement of the head, or head and neck, of the femur. Made of SMo stainless steel, it offers maximum strength; is non-corrosive, non-irritating and completely inert. It may be boiled or autoclaved for sterilization.

Features of Eicher Prosthesis are:

1. Made of one-piece SMo stainless steel to achieve greatest assurance against unfavorable body reaction.
2. Proven stress requirements.
3. Abuts against remaining bone to meet natural lines of force.
4. Shape allows for minor adjustments under functional stress.

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Successfully Used in

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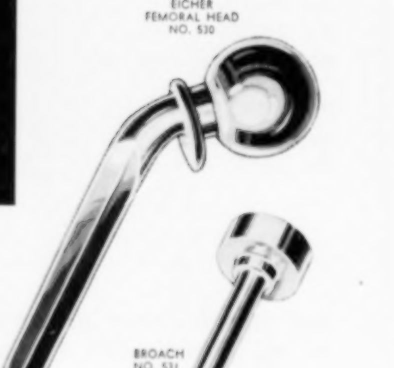

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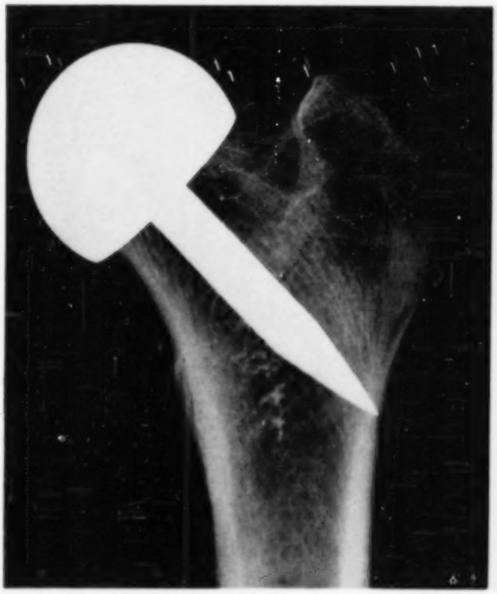

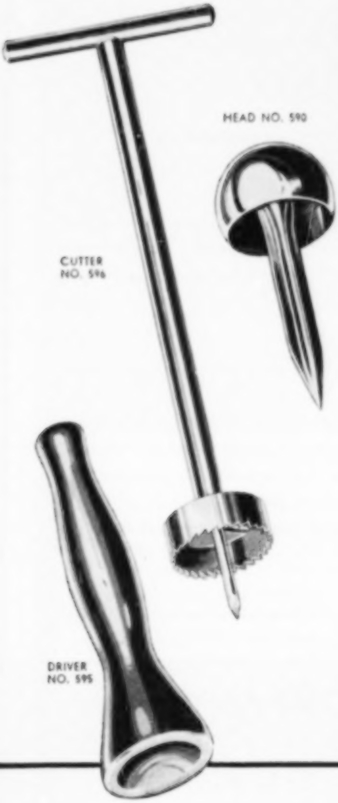

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Norcross, B. M., *N. Y. State J. Med.* **51**: 2356, Oct. 15, 1951.

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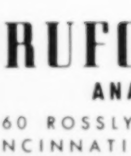

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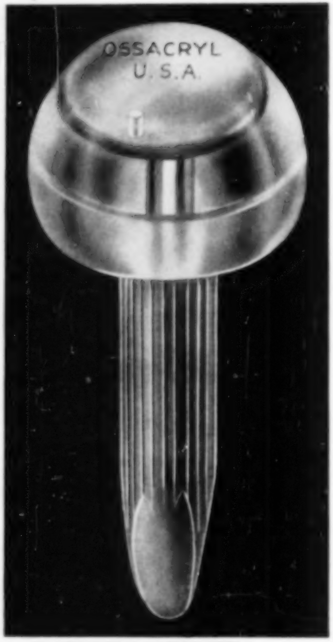

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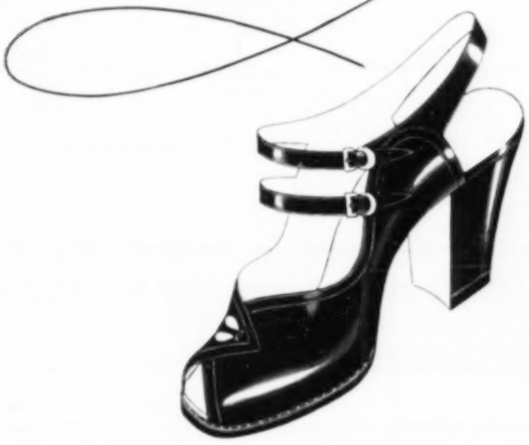

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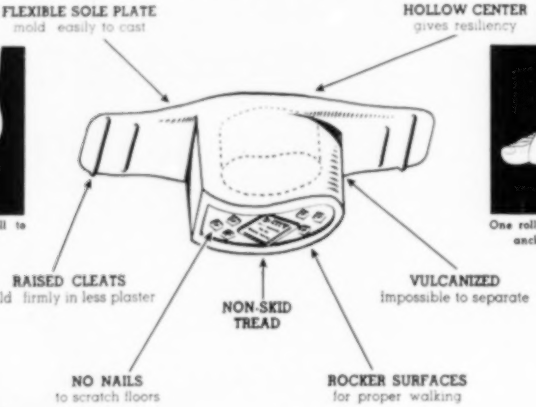
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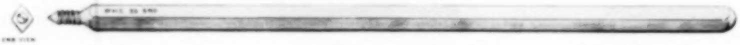

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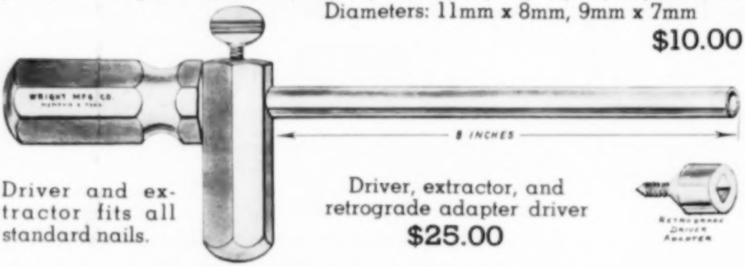
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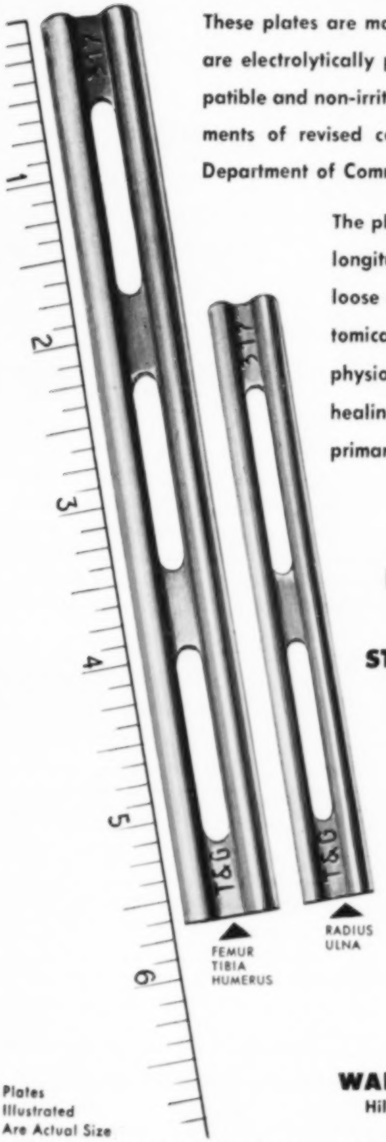

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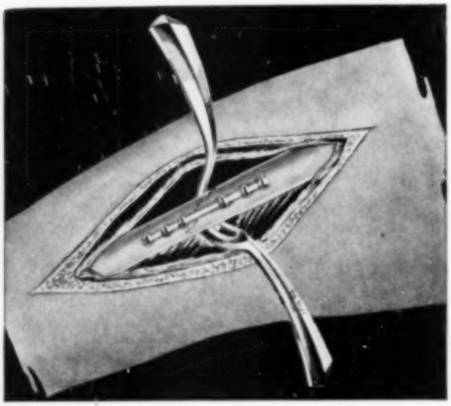

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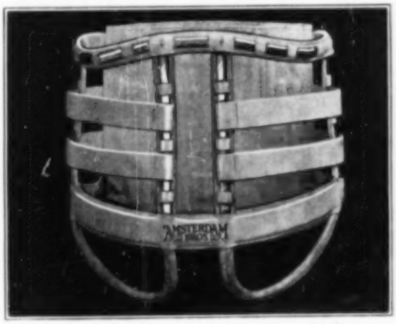

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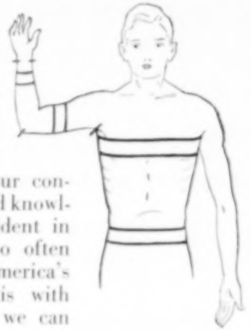

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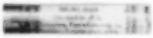

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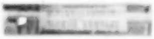

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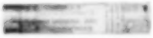

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JANUARY 1952

American Volume
Vol. 34-A, No. 1

8 THE FENWAY, BOSTON 15, MASSACHUSETTS, U. S. A.
BRITISH OFFICE:
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The Journal of Bone and Joint Surgery

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THE JOURNAL OF BONE AND JOINT SURGERY

American Office
8 The Fenway, Boston 15, Massachusetts, U.S.A.
***Assistant Editor:* Florence L. Daland**

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82 Portland Place, London, W. 1, England

VOL. 34-A, NO. 1 JANUARY 1952

The Journal of
Bone and Joint Surgery

American Volume

LOCAL STIMULATION OF GROWTH OF LONG BONES

A Preliminary Report*

BY CHARLES N. PEASE, M.D., CHICAGO, ILLINOIS

From the Children's Memorial Hospital, Chicago

Limb-length differences in children have been treated by orthopaedic surgeons in a variety of ways, none of which has been altogether satisfactory.

The first practical procedure for the regulation of the growth of long bones was presented by Phemister [14] in 1933. Since then, so much emphasis has been placed on epiphyseal arrest that the majority of orthopaedic surgeons have accepted this as the most feasible approach to the problem of equalization of limb length. In general, opinions differ only as to the technique for arresting the growth of the long limb.

It is well known that increased vascularity in the vicinity of or within the long bones of children produces accelerated bone growth. This occurs in congenital or acquired anomalies in the blood supply, local infectious processes, cystic disease, tumors, trauma, and surgical procedures on bones and soft tissues adjacent to the bone. Phemister [15] pointed out that osteomyelitis of the femur frequently produces overgrowth of the corresponding tibia of from one to two centimeters as well as of the femur (Figs. 1-A and 1-B). According to Blount, stapling of the lower femoral epiphysis occasionally results in a slight stimulation of growth in the subadjacent tibia. Haas has been kind enough to review for me his recent work on epiphyseal arrest, obtained by using wires and metal pegs placed in the femur. He also has observed overgrowth in the subadjacent tibia.

In addition, it should be noted that overgrowth of the tibia may also result from fractures of the femur in children. Truesdale and David observed excessive growth of an extremity following fracture of the femur. They assumed that all overgrowth took place in the fractured bone. However, it has been my observation that frequently, in children with fractures of the femur, not only is growth stimulated in the femur but also in the subadjacent tibia (Figs. 2-A through 3-C).

Numerous instances of overgrowth due to various local processes in the extremity have been recorded in recent years, but the first detailed observations were made more than a century ago by Stanley, whose description of overgrowth of long bones was followed shortly thereafter by a similar and equally famous report by Paget.

In some children in whom a fractured femur has been treated by open reduction with fixation by metal plates and screws, considerable overgrowth has resulted, presumably due to the presence of the metallic foreign body. As a result of this experience, the idea of producing irritation of the bone by placing foreign materials within the metaphysis to stimulate growth came into being.

This concept is by no means original. As long ago as 1869, von Langenbeck described

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* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 30, 1951.

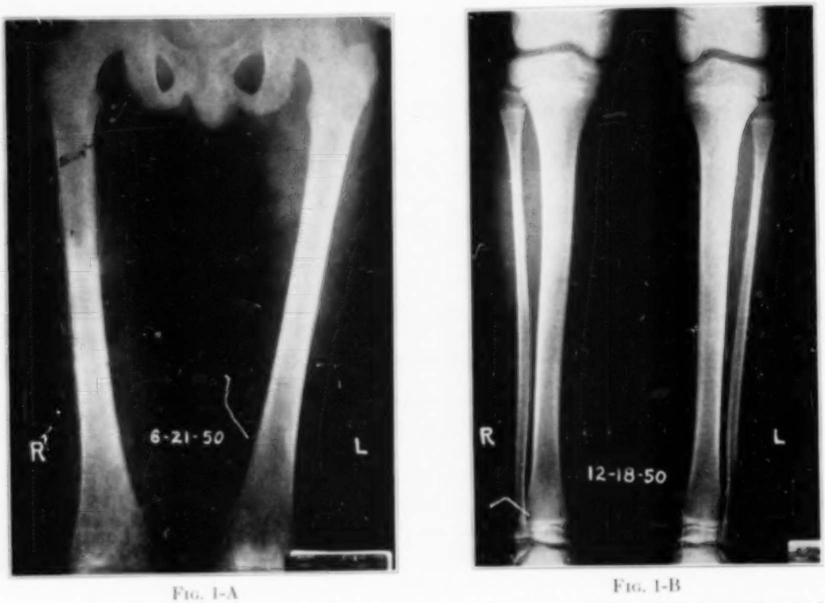

FIG. 1-A

FIG. 1-B

Figs. 1-A and 1-B: L. K., boy, age eleven years. Diagnosis: Osteomyelitis of right femur. Onset of acute hematogenous osteomyelitis on May 19, 1950. X-rays made one month later demonstrate the extent of the inflammatory process in the bone (Fig. 1-A). By December 18, 1950, six months later, there was 0.7 centimeter overgrowth of the femur and 0.4 centimeter of the tibia on the right (Fig. 1-B).

in detail the overgrowth of long bones. He carefully measured the tibiae obtained at the autopsy of a man, seventy-two years old, who had had draining osteomyelitis of one tibia since the age of three years. The diseased tibia was 4.5 centimeters longer than the normal one.

Working on the premise that suppuration in the bone accompanied by a sequestrum acts as a stimulus to growth, von Langenbeck undertook to reproduce these conditions in a dog by using ivory pegs. In 1869, he introduced ivory pegs into the left femur and tibia of an eight-week-old dog to produce the effect of a sequestrum. No infection occurred and the wound healed by primary intention.

Fifteen weeks later the animal was sacrificed, and the femora and tibiae were removed and measured; there was a 0.5 centimeter overgrowth of the femur and a 0.5 centimeter overgrowth of the tibia in which the ivory pegs had been inserted. Since then, many similar experiments have been performed.

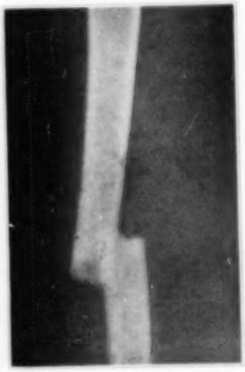

FIG. 2-A

In 1910 Meisenbach injected various chemicals, as well as *Staphylococcus aureus* vaccine, through a large-caliber needle into the upper end of the tibiae close to the epiphyseal plates of growing rabbits without effect. In addition, using a small trochar, he inserted graphite plugs into the bone. Formalin produced more reaction than any of the other materials employed, causing an increase in the thickness of the cortical bone and at the same time producing premature ossification of the epiphyseal cartilage.

In 1929, Bohlman described experiments on ninety-two guinea pigs; he drilled holes in four different locations in each of a series of four animals,—one into the V of the epiphyseal plate, two on each side of the metaphysis close to the plate, and one in the epiphysis as close to the plate as possible. Twenty-two different materials or combinations of substances were placed in the drill holes. These included, among others, iron, copper, wood, ivory, vaccine paste of *Staphylococcus aureus*, and oils of various kinds. Bohlman concluded that foreign materials not only did not produce an increased growth in length of the bones, but often actually caused a pronounced shortening. He stated: "This series of experiments does not warrant the clinical or surgical use of foreign materials in the epiphyseal cartilage plate region to promote the length-growth of bones". Despite these discouraging results, he stated: "More experimental work, with a view to their possible use in bone surgery, should be done".

In 1933, Ferguson found that stimulation of bone growth occurred as a result of drilling holes in the metaphysis and curretting the medullary canal. This procedure revealed some stimulation of bone growth, but the growth was not sustained.

Wu and Miltner, in 1937, performed experiments similar to those of Meisenbach, Bohlman, and Ferguson, but also included periosteal stripping of the long bones. They concluded that these methods failed to produce significant increased growth in length. Their experiments on periosteal stripping produced an increase in growth of from 5 to 15 per cent. during the first three months, but this rate of growth was not sustained after that time.

In 1941, I performed the periosteum-stripping operation on a child eleven years old, with a leg-length discrepancy due to poliomyelitis. In addition to the stripping, tibial-bone segments were placed between the periosteum and the shaft of the tibia. This resulted

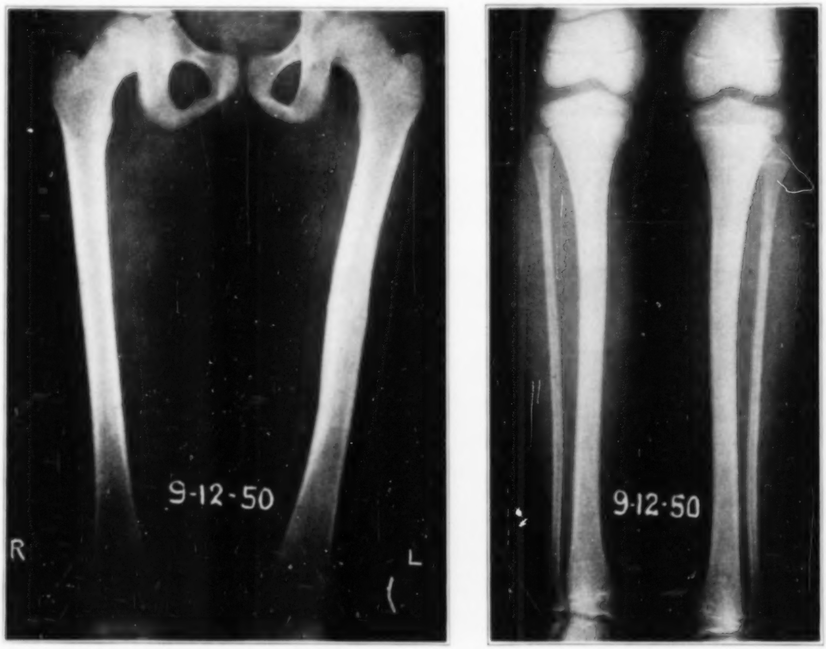

FIG. 2-B

FIG. 2-C

Figs. 2-A, 2-B, and 2-C: A. G., girl, age six years. Diagnosis: Fracture of left femur. This child had a transverse fracture of the middle third of the left femur which was allowed to heal with 2 centimeters of overriding (Fig. 2-A). Three years later, September 12, 1950, the left femur showed an overgrowth of 1.8 centimeters (Fig. 2-B) and the left tibia of 0.3 centimeters (Fig. 2-C).

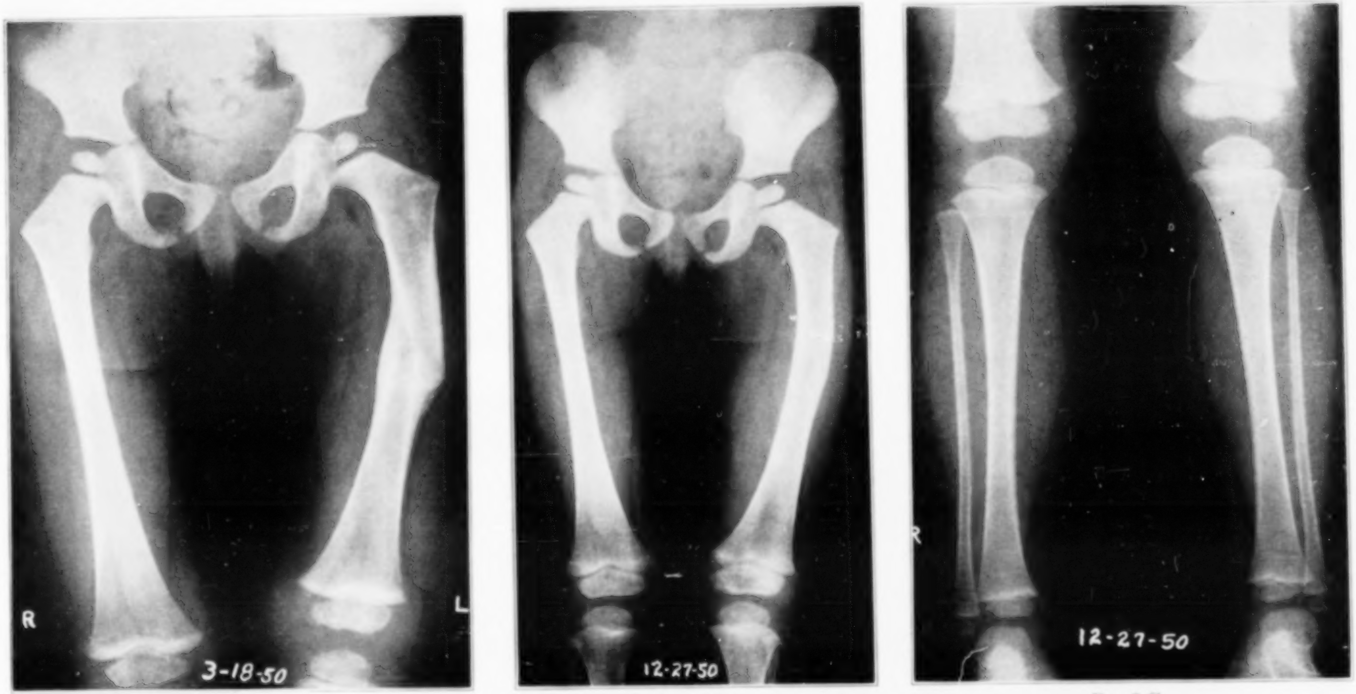

FIG. 3-A FIG. 3-B FIG. 3-C

Figs. 3-A, 3-B, and 3-C: E. F., girl, age two years. Diagnosis: Fracture of left femur. This child sustained a mid-shaft, transverse fracture of the left femur which healed with 1.0 centimeter of shortening and angulation (Fig. 3-A). One year after fracture there was only 0.7 centimeter of shortening of the left femur (Fig. 3-B) and 0.3 centimeter of overgrowth of the left tibia (Fig. 3-C).

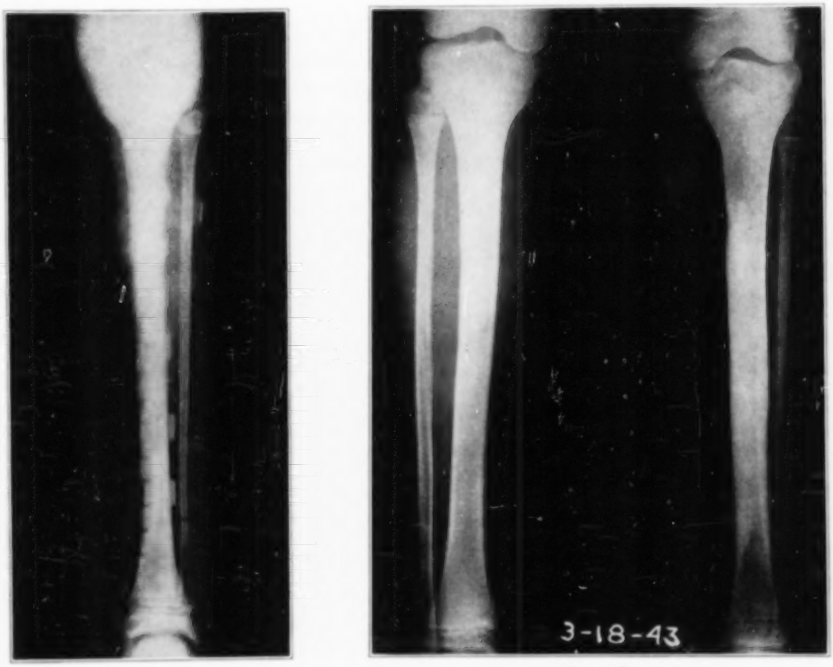

Fig. 4-A Fig. 4-B

Figs. 4-A and 4-B: A. T., boy, age ten years. Diagnosis: Poliomyelitis, onset at five years of age. At the age of ten years, operation was performed which included periosteum-stripping and the insertion of tibial-bone segments subperiostially (Fig. 4-A). Twenty-eight months after the operation, 1 centimeter of overgrowth had occurred and there was some increase in the diameter of the shaft of the tibia. The fibula was not affected; it remained short and atrophic (Fig. 4-B). Unfortunately stimulation of the tibia was not sustained.

in an increase in the transverse diameter of the bone and some acceleration of longitudinal growth, but the latter was not maintained (Figs. 4-A and 4-B).

During 1940 and 1941, Haas inserted foreign bodies about the epiphyseal plate experimentally. He used iron, copper, aluminum, magnesium, and growth-hormone powder. No stimulation of longitudinal growth occurred in any of the experiments. Moreover, magnesium-oxide powder caused tissue destruction with resultant retardation of growth. Because of the negative findings, Haas did not report his painstaking work.

The most recent experiments on the effects of metals on the growth centers of bones in dogs, guinea pigs, and rabbits, were published in 1948 by Chapchal and Zeldenrust. These investigators used various metals, metal alloys, and ivory, placed not only in the metaphyses but also in the epiphyses of the bones comprising the knee joint. They concluded that some lengthening of the bones was attained, but that the amount of growth stimulation was minimal and uncertain. They noted furthermore that, following the insertion of foreign materials, deformities of the bones resulted. They stated, therefore, that the procedure was not suitable for human practice and endorsed Phemister's epiphyseodesis as the best means of solving the problem of inequality of limb length.

The explanation is not clear why some of these investigators were not able to reproduce stimulation of longitudinal bone growth in animals experimentally, comparable to that observed in humans clinically. However, having observed the reaction of growing bone to foreign material in the human, it did not require too much courage to attempt procedures to stimulate bone growth in children with shortened extremities which were

TABLE I-A

Case	Sex	Diagnosis	Age at Onset	Operation			Length Difference	
				Age (*Years*)	Date	Type	Femur	Tibia
							(*Centimeters*)	
Case 1 M. F.	F.	Congenital hypoplasia right leg.	Birth	2½	Oct. 31, 1939	(1) Two Vitallium screws in distal femur only.	2.2	0.3
				7½	Oct. 24, 1944	(2) Removal of Vitallium screw; insertion of two vanadium screws in tibia and femur, respectively.	2.4	0.5
Case 2 L. A.	M.	Poliomyelitis, right leg.	3 years	8	Oct. 5, 1948	Two brass screws in tibia and femur.	1.1	1.3
Case 3 J. S.	M.	Poliomyelitis, right leg.	1 year	5	Sept. 30, 1947	(1) Two brass screws in tibia and femur.	1.1	1.2
				8	May 29, 1950	(2) Removal of brass screws: insertion of two stainless-steel screws in medullary canal of femur and two ivory screws in tibia.	1.5	0.9
Case 4 P. K.	F.	Poliomyelitis, left leg.	2 years	5	Sept. 21, 1949	Two brass screws in tibia and femur.	1.3	1.7
Case 5 D. B.	F.	Poliomyelitis, right leg.	2 years	8	Nov. 16, 1948	Two brass screws in tibia and femur.	0.7	1.3
Case 6 T. H.	M.	Congenital dislocation right hip; hypoplasia right femur.	Birth	3½	Mar. 18, 1950	Two 3/16″ ivory screws in femur only.	2.5	0
Case 7 J. C.	F.	Poliomyelitis, left leg.	10 months	2	June 20, 1950	Two 3/16″ ivory screws in femur and tibia.	1.2	1.0

destined to remain short, become shorter, or even require preparation for a prosthesis.

We were encouraged to attempt this procedure by several considerations. In the first place it is so simple and safe that it is feasible to attempt to correct a potential disparity of only an inch. In the past many orthopaedic surgeons have been content to accept this much shortening, assuming that compensation for this will be provided by a tilt of the pelvis, but disregarding the probable development of low-back pain in later life as a result of this asymmetry.

Another consideration was the natural objection of many parents to operations on the normal limb. Frequently they cannot reconcile themselves to a long period of waiting preparatory to an epiphyseal arrest. They are eager to try any operative procedure on the short limb to produce stimulation of its growth, even if the results are uncertain.

Finally there are the obvious advantages of any operation which will increase the length of the short limb. The rationale of such a procedure can best be illustrated by a case of poliomyelitis in which one leg is paralyzed. Assuming that this extremity was normal prior to illness, it must have the same number of epiphyseal cartilage cells as the opposite extremity. The retarded growth of the affected limb is therefore due to impaired physiology and function of this extremity. The two main factors are loss of stimulation due to stress and strain and decrease in blood supply.

In accordance with this line of reasoning, Harris has demonstrated that the cells in the cartilage columns of the epiphyseal plate undergo degenerative changes in such cases.

TABLE I-B

Case	Follow-Up Examination				Growth After Operation				Calculated Stimulation	
	Age (*Years*)	Date	Length Difference		Normal Leg		Short Leg			
			Femur	Tibia	Femur	Tibia	Femur	Tibia	Femur	Tibia
			(*Centimeters*)		(*Centimeters*)		(*Centimeters*)		(*Centimeters*)	
Case 1 M. F.	7½	Oct. 23, 1944	2.4	0.5	13.0	10.0	10.8	9.7	0.2	0.0
	14½	Dec. 23, 1950	4.9	0.5*	12.9	11.8	11.7	17.7	0.1	1.3
Case 2 L. A.	10	Dec. 1, 1950	0.2*	0.2	5.0	3.1	6.3	3.2	1.5	1.3
Case 3 J. S.	8	May 29, 1950	1.5	0.9	7.4	4.6	7.0	4.9	0.6	0.6
	8½	Jan. 22, 1951	1.8	0.8	0.5	0.3	0.5	0.4	0.2	0.0
Case 4 P. K.	6	Dec. 16, 1950	0.7*	1.1	4.0	2.6	6.0	3.2	2.2	0.8
Case 5 D. B.	10	Dec. 11, 1950	0.2	0.5	1.7	0.9	2.2	1.7	0.6	0.9
Case 6 T. H.	4	Jan. 5, 1951	2.0		2.2		2.7		0.8	
Case 7 J. C.	3 1/12	Jan. 6, 1951	0.7	0.7	2.2	1.3	2.7	1.6	0.7	0.4

* These cases showed overgrowth of the short side so that the figures marked by an asterisk represent the amount by which this bone of the affected extremity now exceeds that of the normal side in length.

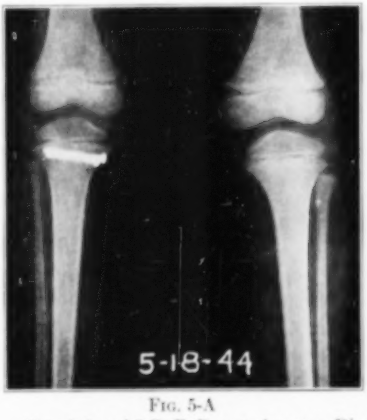

Fig. 5-A

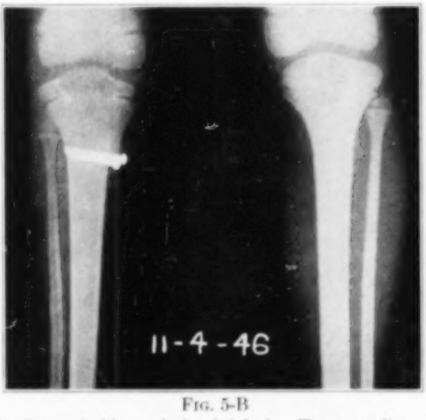

Fig. 5-B

Figs. 5-A and 5-B: P. B., age six years. Diagnosis: Congenital hypoplasia of right leg. Two vanadium screws were inserted into upper end of tibia on May 2, 1944 (Fig. 5-A). Thirty-one months later (Fig. 5-B), there was considerable increase in the transverse diameter above screws, apparently due to growth stimulation and to the resistance to adjacent soft-tissue pressure by heads of screws. The fibula was not affected.

He stated: "Cessation of proliferation, senescence, and death can only be avoided by the acquisition of a new irrigation system whereby a supply of nutritive fluid can be guaranteed to those cells which are situated in a region of minimum food supply or oxygen starvation".

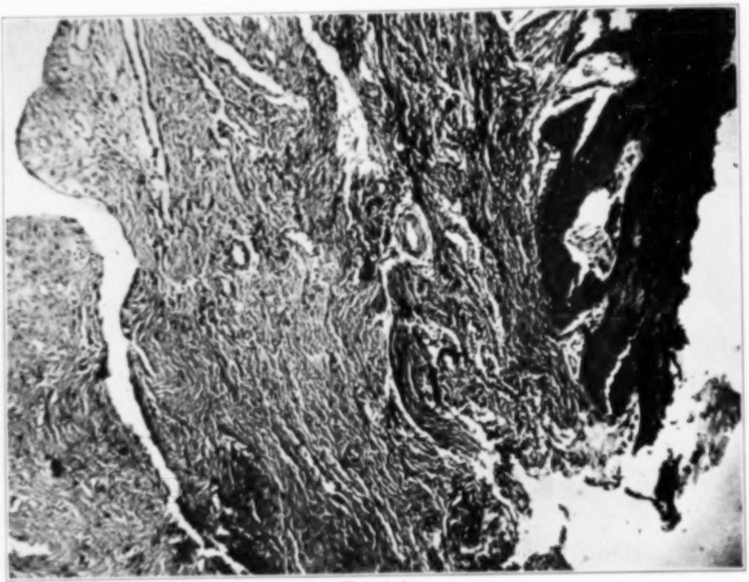

Fig. 6-A

Photomicrograph (× 60) of tissue taken from screw holes in case of P. B. after removal of vanadium screws (Fig. 5-A and 5-B). Note connective tissue with dense collagen and numerous focal collections of small round cells.

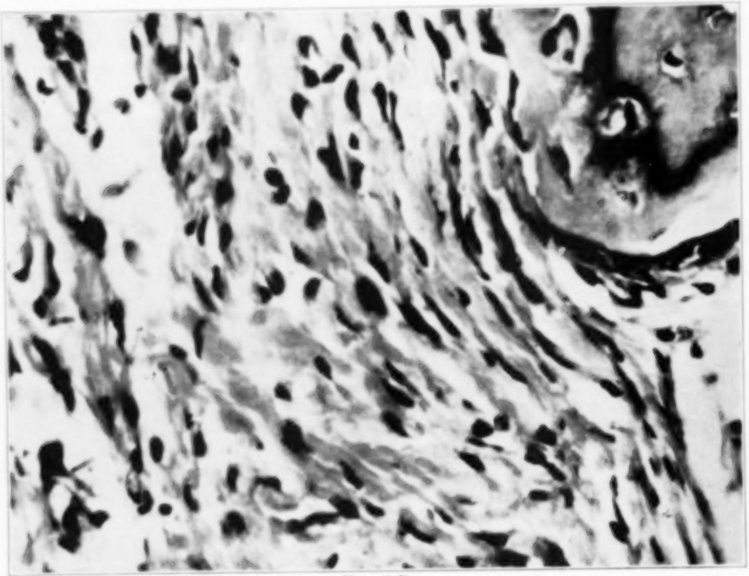

Fig. 6-B

Higher magnification (× 450) of the tissue shown in Fig. 6-A.

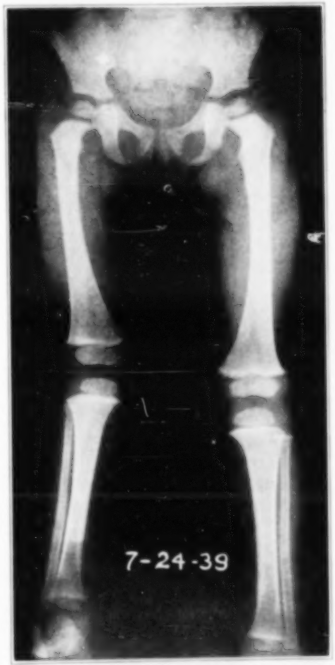

FIG. 7-A

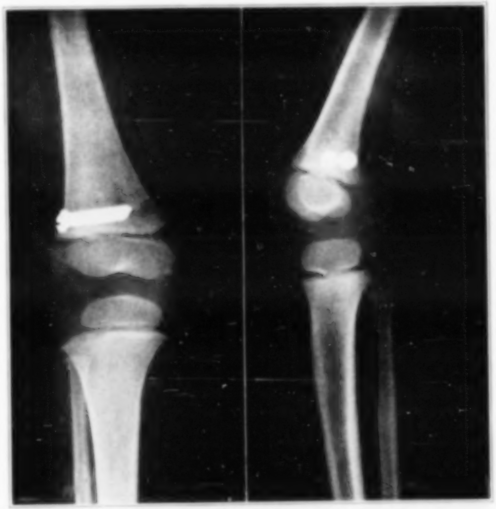

FIG. 7-B

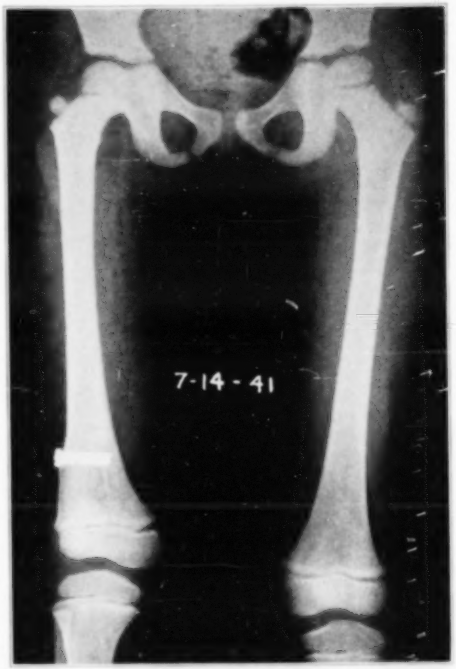

FIG. 7-C

Figs. 7-A through 7-N: Case 1. M. F., female. Age two and one-half years. Diagnosis: Congenital hypoplasia of right femur. She was first seen July 24, 1939, when x-rays showed slight knock-knee on the right and 1.9 centimeters shortening of the femur and 0.3 centimeter of the tibia (Fig. 7-A). On October 31, 1939, two Vitallium screws were inserted in the femur (Fig. 7-B). After one year and eight months, x-rays (Fig. 7-C) showed an increase in the transverse diameter of the lower portion of the femoral shaft chiefly below the screws. After almost five years, x-rays (Figs. 7-D and 7-E) showed persistent shortening amounting to 2.4 centimeters in the femur and 0.5 centimeter in the tibia on the right. The films show maintenance of the increased transverse diameter of the femoral shaft distal to the screws. This indicated continued stimulation even after the screws had receded a considerable distance from the epiphyseal plate, due to growth. However, it was felt that effective stimulation had ceased at this time; therefore, on October 24, 1944, the two Vitallium screws were removed and were replaced by four vanadium screws,—two in the distal portion of the femur and two in the proximal portion of the tibia, both close to the corresponding epiphyseal plate (Figs. 7-F, 7-G, and 7-H). Two years after this (Figs. 7-I and 7-J), the screws were shown to be still parallel and in the same plane. However, after four years crossing of the screws occurred, indicating considerable differential growth in the femur (Fig. 7-K), which became even more marked after six years (Fig. 7-L). More rapid bone growth had occurred at the head of one screw and at the end of the other. In contrast to this there was little or no change in the position of the tibial screws during the six-year period. However, both femur and tibia showed increased transverse

(*Continued on page 10*)

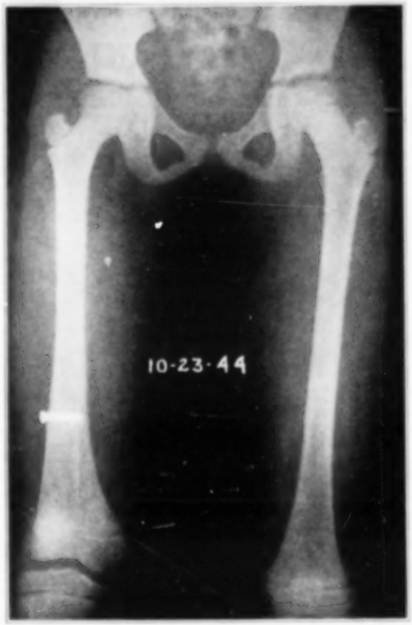

FIG. 7-D

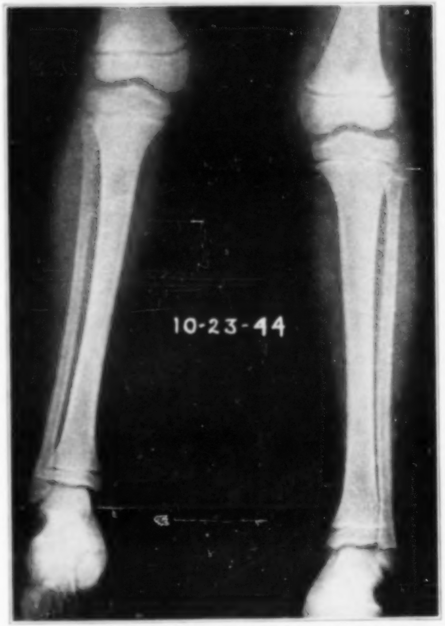

FIG. 7-E

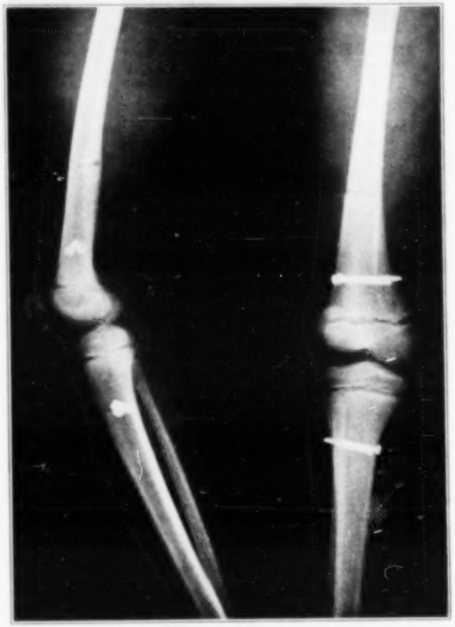

FIG. 7-F

(*Continued from page 9*) diameters of their respective distal and proximal portions (Figs. 7-M and 7-N). Measurements at this time, December 23, 1950, revealed the right femur to be 4.9 centimeters shorter and the right tibia to be 0.5 centimeter longer than the corresponding bones on the left. This represented a total overgrowth of 1.2 centimeters of the right tibia, which occurred in spite of the fact that the epiphyses of this bone were underdeveloped.

Because of shortening amounting to 4.4 centimeters on the right at this time, epiphysiodesis on the left was performed on December 29, 1950.

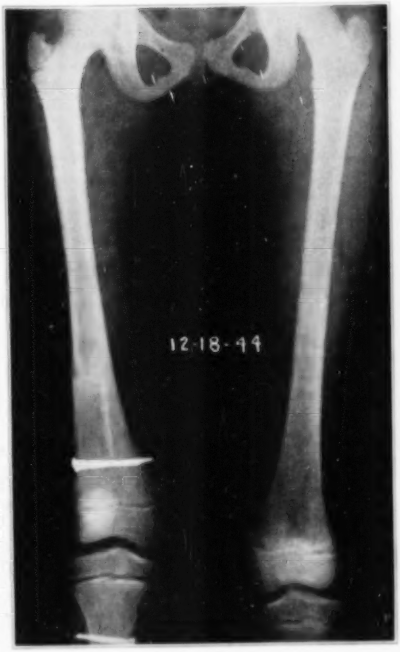

FIG. 7-G

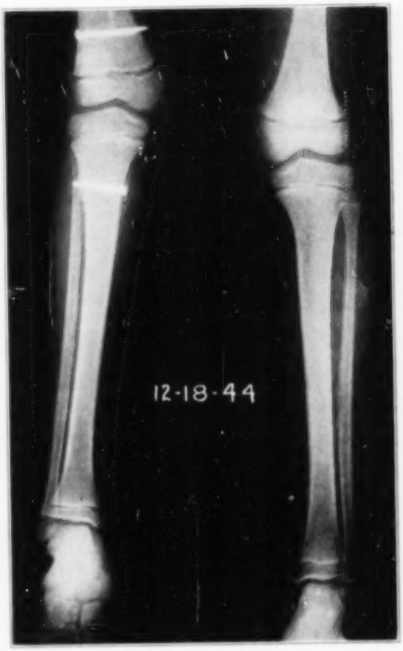

FIG. 7-H

Although there was no conclusive experimental evidence to confirm Harris's hypothesis concerning the value of increasing the blood supply to the cells of the epiphyseal cartilage, ten cases have been treated by the insertion of metal or ivory screws in the metaphyseal region close to the cartilage plate. Five of these were cases of congenital hypoplasia and five were poliomyelitis. In all of them an increase in the rate of growth occurred after the operation. However, it is impossible to determine how much of this was actually due to the procedure. In the cases of hypoplasia, the epiphyseal cartilage plates were not normal and there is no way of knowing how growth would have occurred had there been no operative interference. Furthermore, in cases of poliomyelitis it is impossible to predict how much growth retardation, if any, will result. For this reason only those cases of poliomyelitis were selected for operation in which growth on the affected side was falling behind that of the opposite extremity at the time of surgery.

To facilitate calculation of the effects of operation, the following formula has been used. It is of particular value in the cases of infantile paralysis, but also may be used to follow the rate of growth where there is inequality of limb length, and it is desired to observe growth for a period of time. The formula is as follows:

Where A = length of short bone at time of operation,
B = length of corresponding bone on the opposite side at operation,
A' = length of short bone after interval of growth,
B' = length of corresponding bone after interval of growth, and
X = calculated length of the short bone after interval of growth,
Then X can be determined by the proportion: $A:B :: X:B'$

If the growth rate of the shortened bone is the same as on the normal side, then X will equal A', the actual measurement. If there is excessive growth of the shortened bone, X should be less than A'. Conversely, if the growth is not keeping pace, X will be more

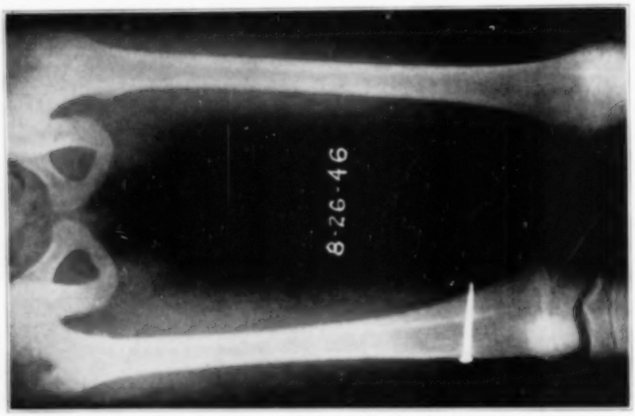

Fig. 7-I

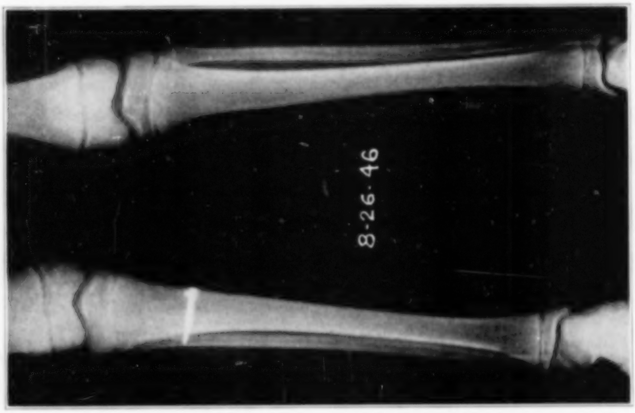

Fig. 7-J

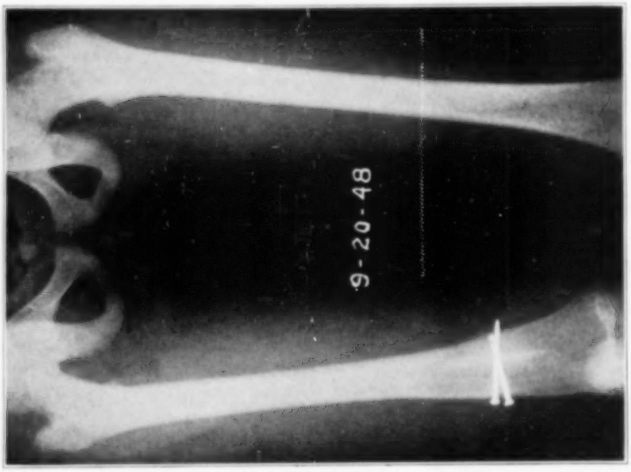

Fig. 7-K

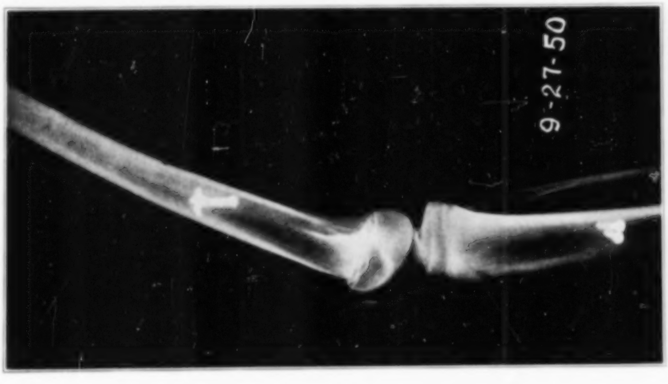

Fig. 7-L

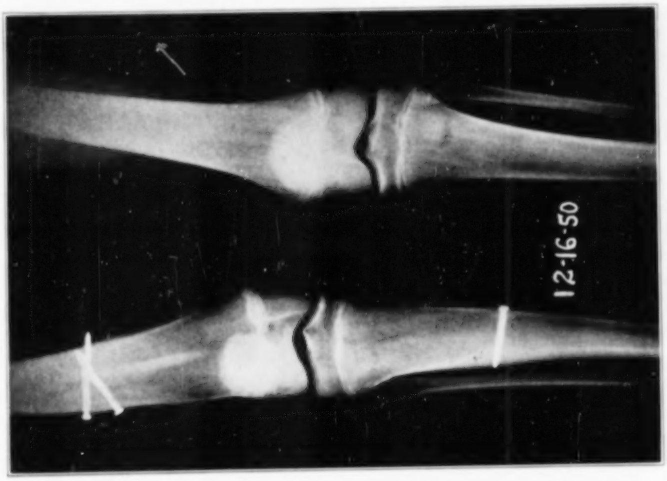

Fig. 7-M

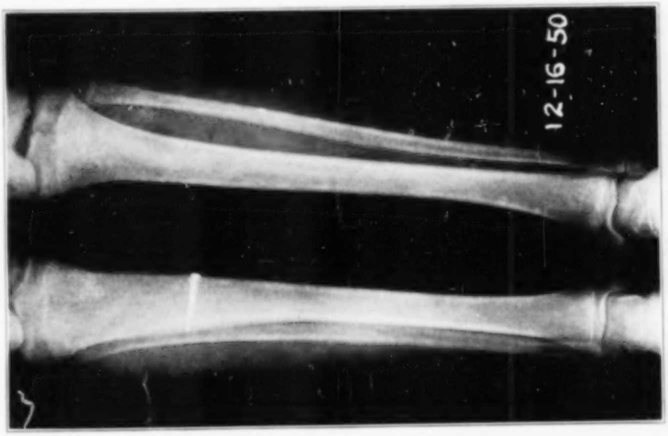

Fig. 7-N

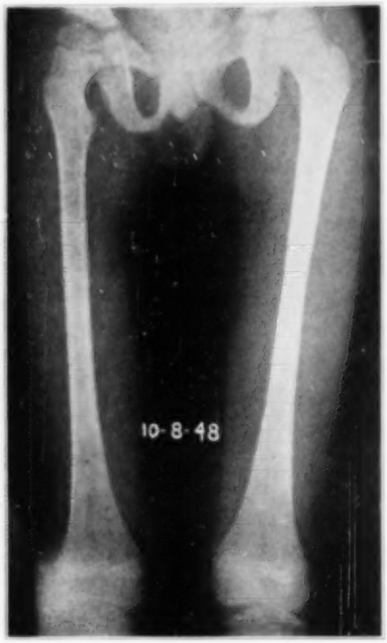

FIG. 8-A

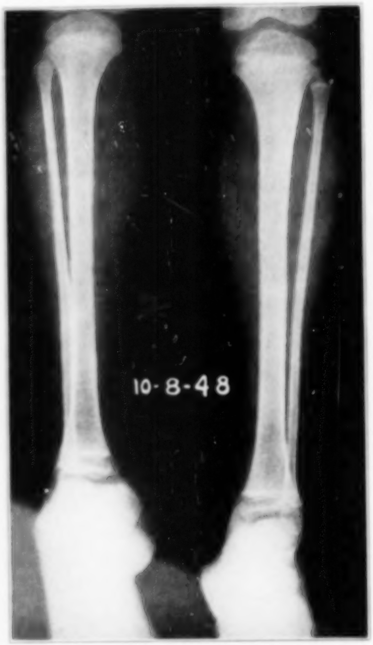

FIG. 8-B

than A'. This formula was used to calculate the stimulation of growth of the cases reported in the table. Its use is illustrated in Case 2 (Figs. 8-A to 8-J).

Although in cases of unilateral congenital hypoplasia prediction of growth is impossible, in poliomyelitis a more exact estimate of growth is possible. Here too, however, there are so many variables that an entirely accurate prediction cannot be made. For instance, there are over sixty possibilities of retarded growth in the femur and tibia of a child with only one major muscle of the leg affected. The number of variations will depend upon the degree of involvement, the age of the child, the amount of weight-bearing, and whether or not a brace was worn and, if so, for how long.

How much growth stimulation can be expected is also variable. If extensive paralysis exists and inadequate use of the extremity decreases the normal stimulation resulting from stress and strain, more rapid degeneration of the cell colonies in the epiphyseal plate can be expected. Skillful evaluation of the existing factors is important in selecting the optimum time to initiate growth stimulation. Obviously, the sooner more normal physiological conditions are restored about the epiphyseal plate of the paralyzed limb, the more favorable will be the result. It is my opinion that growth stimulation procedures, if indicated, should be started within two years after an attack of poliomyelitis.

To study the results of these procedures some method of measuring limb length is essential. The most accurate method is by orthoroentgenography as described by Green, Wyatt, and Anderson. Unfortunately, not all of us are equipped at present to carry out such measurements and we must be content with teleoroentgenograms, lengths calculated from the films made at shorter distances, or by clinical measurement from the anterior superior spine of the ilium to the tip of the medial malleolus.

When present, variations in children's bones may be used as identification markers—notably the so-called transverse lines of arrested growth. In some of the cases which are presented here, phosphorous in its natural state, or as phosphorized cod-liver oil, has been

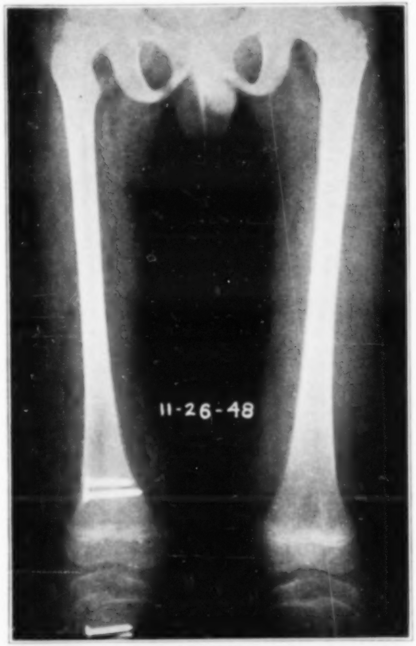

FIG. 8-C

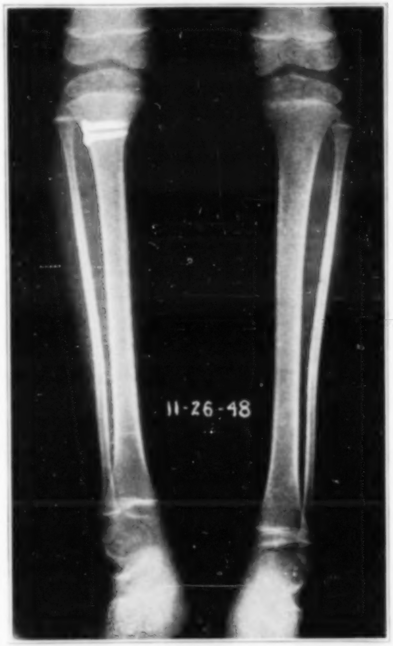

FIG. 8-D

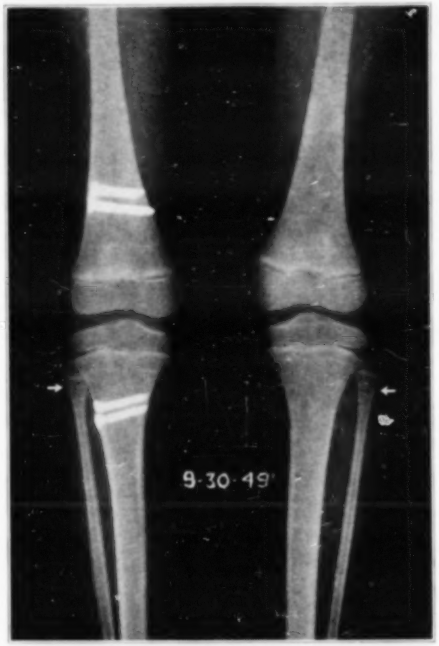

FIG. 8-E

Figs. 8-A through 8-J: Case 2. L. A., male, age eight years. Diagnosis: Poliomyelitis was contracted at the age of three years with paralysis of right leg. He was admitted on October 4, 1948. Muscle power about the hip, thigh, and calf ranged from + + to + + +. X-rays (Figs. 8-A and 8-B) showed that the left femur measured 36.1 centimeters and the right femur 35.0 centimeters, and that the left tibia measured 29.0 centimeters and the right tibia 27.7 centimeters. Prior to admission, he had received one tablespoon of phosphorized cod-liver oil daily for three weeks. On November 5, 1948, brass screws were inserted into both the femur and tibia with their heads in contact as shown in Figures 8-C and 8-D. Ten months later on September 30, 1949 the measurements of the femora were, left 38.6 centimeters and right 38.3 centimeters, and the measurements of the tibiae were, left 31.4 centimeters, right 30.9 centimeters (Fig. 8-E). The lines of "arrested growth" produced by the phosphorized cod-liver oil showed increased growth of the right femur and proximal tibia, the stimulated bones, but not of the right fibula. X-rays taken fifteen months after the operation, February 22, 1950, showed continued stimulation with beginning asymmetrical growth, evidenced by the divergence of the screw ends on the femur and the upward angulation of the tibial screws (Fig. 8-F). Stimulation of the distal right tibial epiphysis was also noted at this time (Fig. 8-G). Finally on December

(*Continued on page 17*)

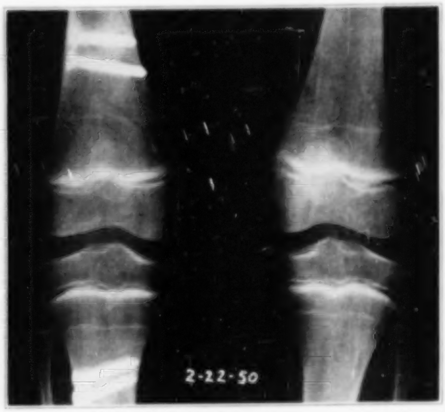

Fig. 8-F

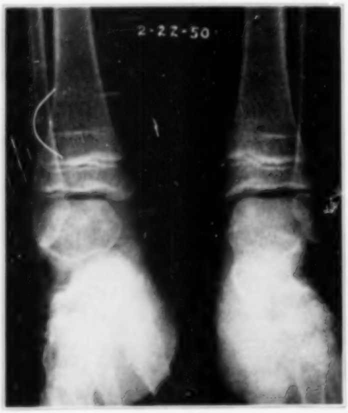

Fig. 8-G

used to produce layers of dense bone to facilitate measurement. A teaspoonful to a tablespoonful of phosphorized cod-liver oil given daily for three or four weeks will suffice for any child under the age of seven to ten years. In older children .006 gram, administered two or three times a day for one month, will produce a similar result.

Phosphorus in such small doses will not, as far as can be discerned, produce harmful effects. These lines of "arrested growth" have been proved to be normal compact bone by Adams in experiments on rabbits, and by microscopic studies of bones of children made by Hatcher.

In the experiments presented, I have used Vitallium, stainless steel, vanadium, brass and ivory screws. At present, ivory is used almost exclusively. Although the results appear to be the same, regardless of what type of foreign material is placed in the metaphysis, it would seem that the ivory screws are more effective, inasmuch as no oedematous fibrous tissue capsule forms about them as in the case of metal screws (Figs. 5-A and 5-B). The walling off of the metal screws by this capsule presumably decreased the irritant reaction of this type of foreign material. Another advantage of the use of ivory screws is that eventually they are absorbed, making possible removal of the screws at a later date unnecessary.

Accelerated growth occurs for a period of two to three years after operation, becoming less as the epiphyseal plate grows away from the region of the foreign material.

Secondary operations are sometimes necessary and, although I have never performed a third or fourth, there should be no objections if the desired effect is accomplished. This should not be a deterrent to use of the method, since it is simple and safe and may make epiphyseal arrest unnecessary, or delay it to a time when only a minor discrepancy exists.

TECHNIQUE

Daily for one month prior to the operation, a teaspoonful to a tablespoonful of phosphorized cod-liver oil is given to the child, the dosage depending upon the age.

The ivory screws or pieces of ivory are sterilized by placing them in a mason or other jar with a screw cap. They are then covered with 95 per cent. alcohol, the screw cover is applied *loosely*, and the jar is placed in the autoclave. The jar and contents are then sterilized under fifteen pounds of pressure for one hour. Conventional sterilization in the autoclave is not recommended, because the ivory becomes brittle under direct prolonged steam pressure. For the same reason the ivory screws should not be stored in alcohol.

Two sizes of ivory screws have been used, three-sixteenths of an inch and one-quarter of an inch. The manner in which they are introduced differs somewhat from that used in

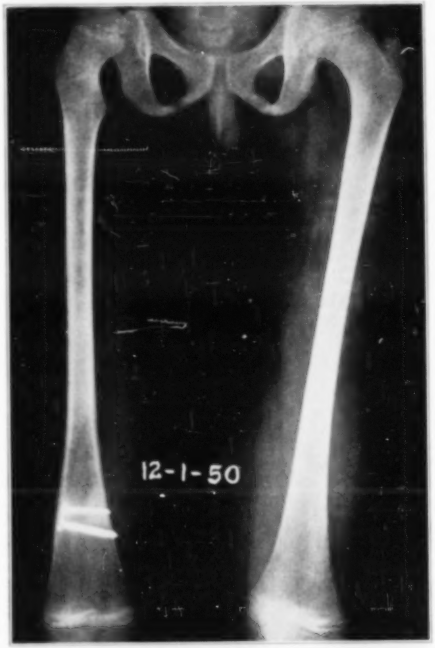

FIG. 8-H

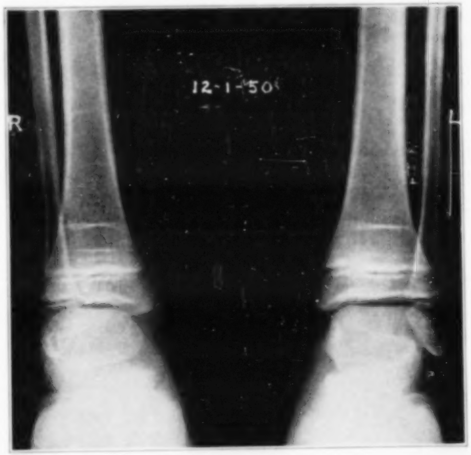

FIG. 8-I

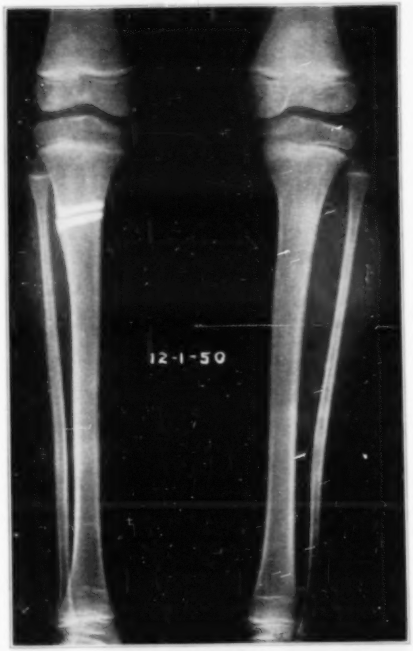

FIG. 8-J

(*Continued from page 15*) 1, 1950, twenty-six months after the operation, the measurements were: femora, left 41.1 centimeters, right 41.3 centimeters; tibiae, left 32.1 centimeters, right 31.9 centimeters. Both limbs were equal at this time (Figs. 8-H, 8-I, and 8-J). It should be noted that there is no effect on some of the bones adjacent to those stimulated, notably of the right patella (Fig. 8-F) and of the right astragalus (Fig. 8-I).

Calculation by the previously described formula (35.0 : 36.1 :: X : 41.1) gives a calculated length of the short femur after growth of 39.8 centimeters. However, the actual measurement was 41.3. Therefore the stimulation produced by operation was 1.5 centimeters. Similarly the right tibia showed a stimulation of 1.3 centimeters, making a total calculated growth stimulation of 2.8 centimeters. This is, of course, purely theoretical, since there is no way of determining exactly what the growth would have been without stimulation.

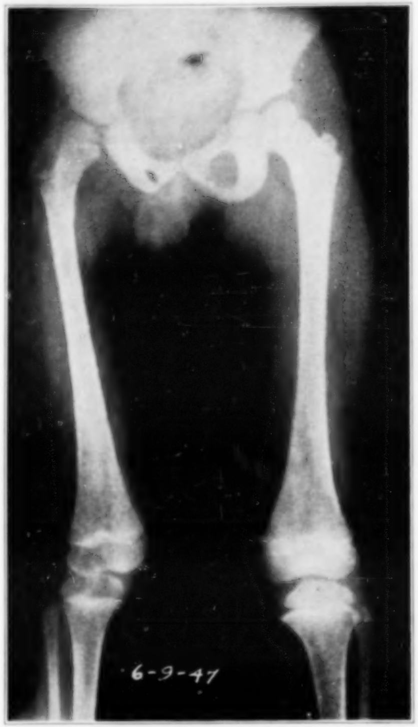

Fig. 9-A

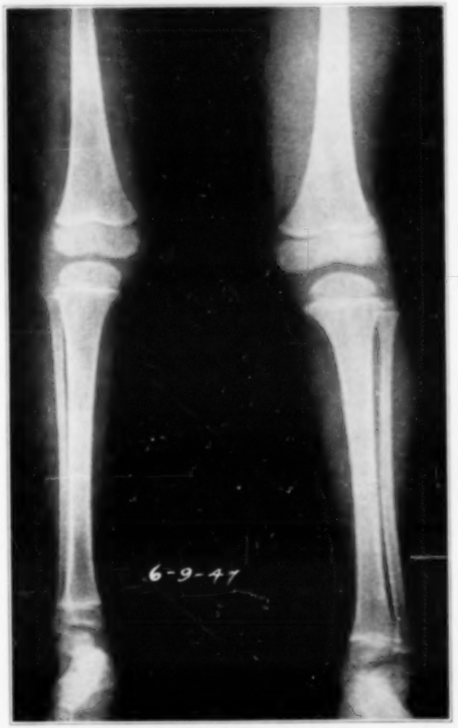

Fig. 9-B

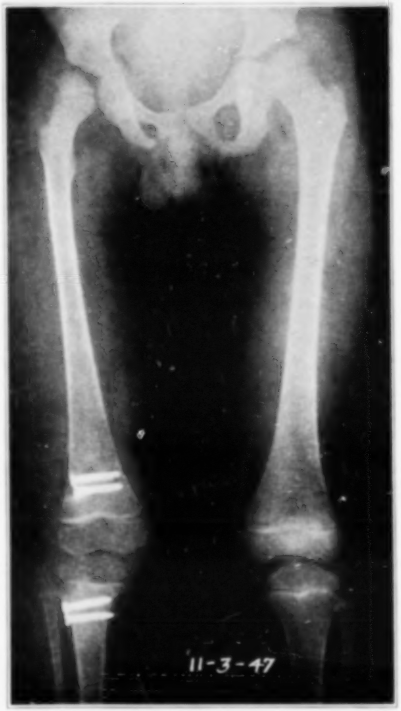

Fig. 9-C

Figs. 9-A through 9-G: Case 3. J. S., male, age five years. Diagnosis: Poliomyelitis contracted at one year of age. When he was first seen the right leg was flail except for + + hamstrings and + quadriceps. By x-rays (Figs. 9-A and 9-B) the right femur was 1.1 centimeters short, the right tibia 1.2 centimeters short. On September 30, 1947, brass screws were inserted in the right femur and tibia as shown in Figures 9-C and 9-D. Two years and eight months after operation measurements revealed the right femur to be 1.5 centimeters short, the right tibia 0.9 centimeter short. Although this represents an increased shortening of the femur amounting to 0.3 centi-

(Continued on page 19)

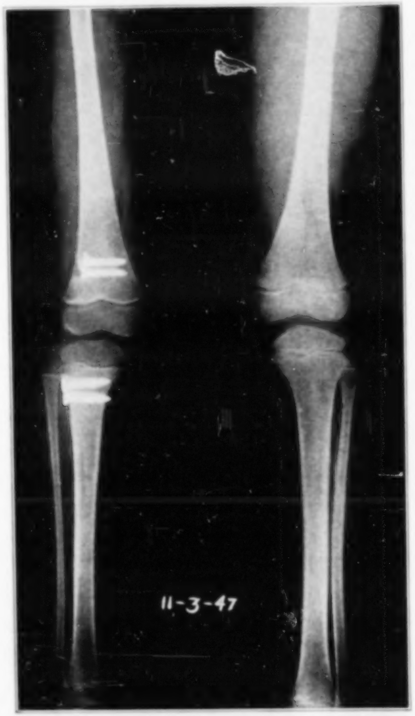

Fig. 9-D

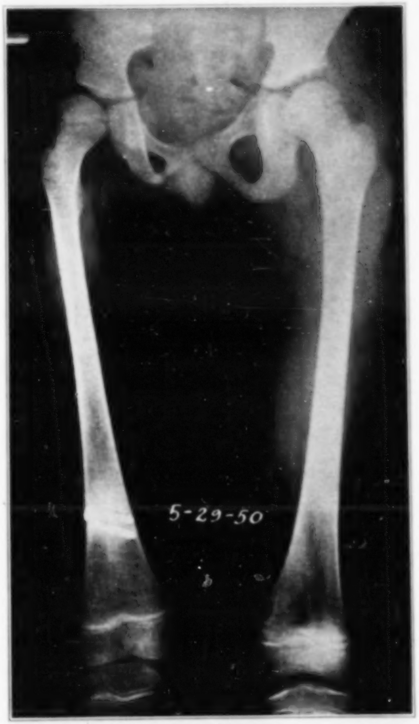

Fig. 9-E

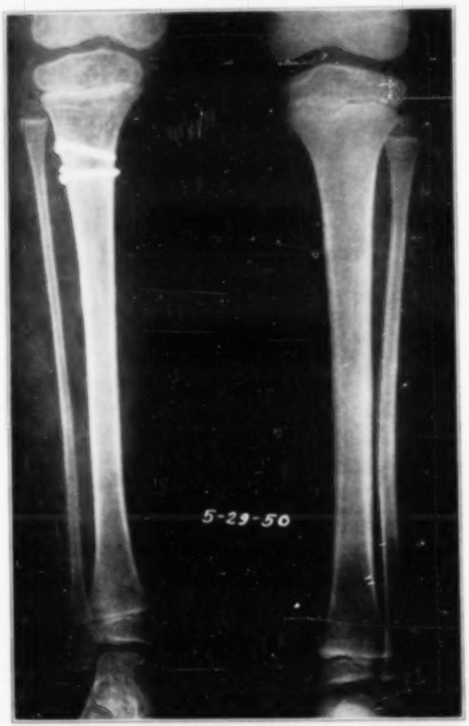

Fig. 9-F

(*Continued from page 18*) meter, the amount of growth was still increased over the theoretical value as calculated by the formula. The right tibia had gained 0.3 centimeter in length over the left (Figs. 9-E and 9-F).

Because of the persistent shortening, on June 20, 1950, the distal portion of the femur was fenestrated and two stainless-steel screws were placed longitudinally in the medullary canal after removal of the brass screw. In the proximal portion of the tibia, two three-sixteenth-inch screws were inserted horizontally. Six months later lines of "arrested growth" showed acceleration of growth on the right (Fig. 9-G).

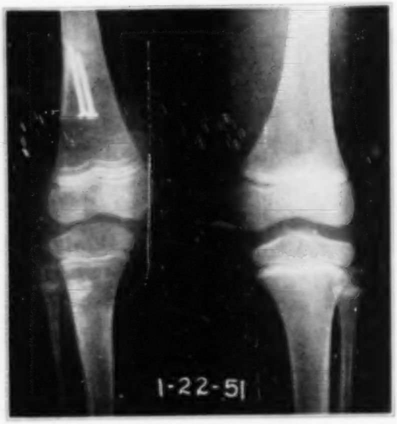

FIG. 9-G

inserting metal screws. After a lateral longitudinal incision has been made at the end of the bone, just enough of the periosteum is stripped to permit drilling the holes. Although the incision is made in the epiphyseal plate region, it is not only unnecessary to expose the cartilage, but it is recommended that the plate be avoided. Not one complication has arisen from this approach, but a word of caution is in order, as too much trauma at the site of the epiphyseal plate may cause an arrest of growth.

Two or three holes are made in the bone, usually one anterior to the other. The size of the drill used depends upon the size of the screw selected. The drill should be at least one-sixty-fourth of an inch smaller than the screw, depending upon the hardness of the bone. If the bone is atrophic, the screws can be driven in without difficulty. If it is hard, an appropriate tap is necessary to thread the bone canal.

The standard ivory screws are two to three inches long, which is considerably longer than is usually necessary. Therefore, after the depth of the drill hole has been determined, a mark is made on the proximal portion of the screw as an indicator of how far the screw must be driven into the bone in order that its distal end will extend just through the opposite cortex. With a bone-cutting forceps, the remaining proximal portion of the screw is then cut off flush with the cortex.

If one prefers, he can fenestrate the bone above the epiphyseal plate and place suitable pieces of ivory or ivory screws in the medullary canal. This was done in one case, using stainless-steel screws (Fig. 9-G).

In the study of these cases, it was observed that, with screws inserted only in the region of the lower femoral epiphyseal plate, stimulation of growth occurred in the subadjacent upper tibial epiphysis. When screws were placed in the upper end of the tibia, accelerated growth also occurred from the lower tibial epiphysis.

RESULTS

Seven cases are reported here with follow-up studies ranging from six months to twelve years. In five the deformity was due to poliomyelitis, in one to congenital hypoplasia, and in one to a congenital dislocation of the hip with associated hypoplasia of the femur. A secondary operation was performed in two cases five and three years after the initial procedure. The results are summarized in Table I.

In all cases stimulation of growth followed operation to a variable degree. No severe deformities occurred, as was the case in the reported animal experiments. In any event, if a deformity did occur, it would prove favorable, as an osteotomy performed correctly will afford additional length, and at the same time produce further stimulation of longitudinal growth.

Included in this study are some interesting observations on the behavior of the bones in which metal screws were placed. The screws were put in parallel and in practically all cases horizontal, most of them extending to or through the opposite cortex. After remaining in a parallel position for a period of two or three years, a crossing of the screws sometimes occurred, the growth at the head of the one being more rapid than at the head of its partner. This affords definite proof of differential growth. This change in position cannot be explained by the screws not going through the cortex on the opposite side with the

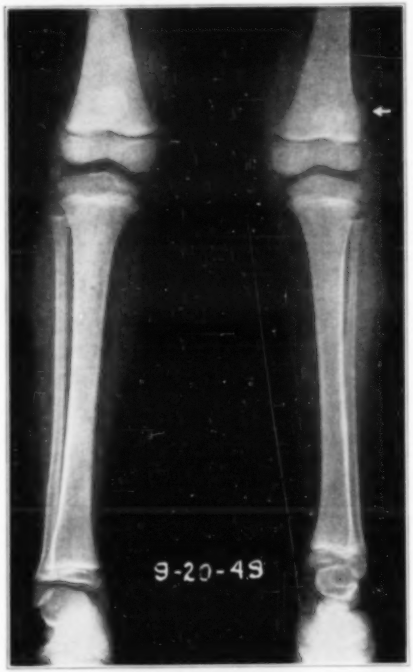

Fig. 10-A

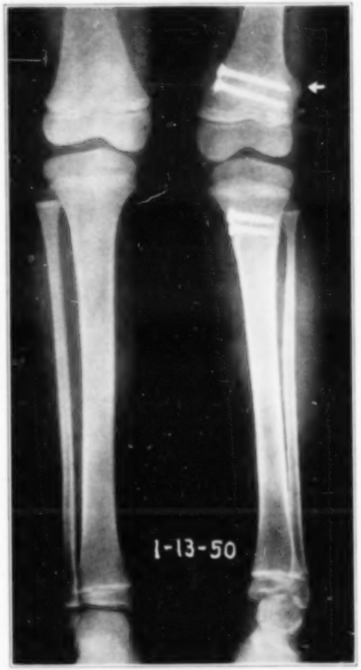

Fig. 10-B

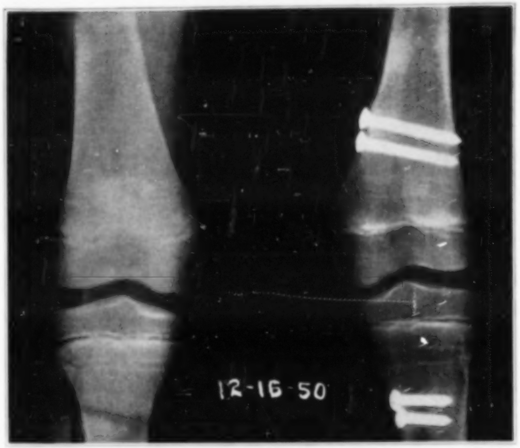

Fig. 10-C

Figs. 10-A, 10-B, and 10-C: Case 4. P. K., female, age four years, ten months. Diagnosis: Acute anterior poliomyelitis at the age of two years. The patient had considerable shortening when first seen two years after onset and definite stimulation of bone growth resulted from the insertion of two brass screws in both the tibia and femur in a manner similar to that described. (See Table I for the results.) An interesting side effect of the procedure was the disappearance of a small osteoma of the femur following insertion of one of the screws near its base. This is presumed to result from the increased blood supply to the area producing demineralization and increased soft-tissue pressure.

result that their ends dropped inferiorly into the medullary canal, for the screws in some cases became angled superiorly in relation to the horizontal plane. (Compare Figures 8-C and 8-D with Figures 8-H and 8-I.)

Another interesting observation was that oftentimes there was an increase in the transverse diameter of the bone in the region between the screw and the epiphyseal plate. This was presumably due to resistance of the metal to the normal soft-tissue pressure against the bone, in addition to the expected increase in transverse growth resulting from stimulation (Figs. 6-A, 6-B, and 7-C).

In one case in which the screw extended into a small exostosis at the lower end of the femur, there was complete disappearance of this tumor in a period of one year. The presumed explanation for this phenomenon is that increased vascularity produced demineralization of the bone in the exostosis to such an extent that normal soft-tissue pressure restored the anatomical contour of the bone (Figs. 10-A, 10-B, and 10-C).

CONCLUSIONS

It should be emphasized that this is a preliminary report and that no valid conclusions can be drawn from so few cases. However, it is encouraging to have definite acceleration of bone growth in four cases of poliomyelitis occurring respectively at three, four, five, and six years after onset of the disease, coincident with growth-stimulating procedures. This suggests that the cells in the cartilage columns of the epiphyseal plates have not undergone degenerative changes during these periods, as would be anticipated from Harris's hypothesis. Further study to determine when and if these premature senescent changes occur is needed.

Much remains to be learned about bone growth in children. Although all of us are familiar with conditions which produce overgrowth of the long bones, we do not know in what percentage of cases this overgrowth persists, or in what percentage of cases there is premature ossification of the epiphyseal plates.

From the conflicting reports in the literature on the results of animal experiments on growth stimulation, it is obvious that animal experimentation is not as yet a reliable tool for the study of growth stimulation of long bones.

Although ivory is being used almost exclusively for bone-growth stimulation, a word of caution should be given concerning the use of metals. Reports of experiments in animals have indicated that certain metals are toxic, notably magnesium.

There are many problems concerning bone growth which are waiting to be solved. It is hoped that this paper will serve to stimulate thought in this direction.

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DISCUSSION

DR. WALTER P. BLOUNT, MILWAUKEE, WISCONSIN: With this very practical paper, Dr. Pease has reopened a subject which has been controversial for many years. Inequality of limb length has always been a challenge to orthopaedic surgeons. If one lower extremity is shorter than the other as a result of disease or congenital deformity of one of the bones, usually the best treatment is to lengthen the short bone. Various stimulating operations have produced little increased length. Dr. Pease has shown some notable exceptions. These operations are less hazardous than the bone-lengthening procedures of Putti, Abbott, and others, which have been largely abandoned.

When the inequality of length is due to overgrowth as a result of bone infection or trauma, it is logical to slow down growth. The operation proposed by Phemister in 1932 is less extensive and in many ways preferable to the direct bone-shortening procedures. I am going to continue to use it in cases in which the result is sure to fall short of complete correction.

I am as enthusiastic as ever about stapling. It can be done earlier than the Phemister operation and it can be done with greater assurance of accurate equalization of length. The hazard of undercorrection or overcorrection is not present. Upon the removal of the staples, growth is resumed.

One method, however, should not be used to the exclusion of others. There is an indication for each. Many times the operations may be used in combination. Dr. Pease's operation should be done early and repeated. If there is also angular deformity of the short leg, an osteotomy to straighten the limb will stimulate growth. A coincident coxa vara is well treated by high femoral osteotomy, sometimes done in several stages using blade-plate fixation. In poliomyelitis, one should not overlook sympathectomy if the extremity is cold and wet. If the short extremity has adequate length, stapling may be considered earlier than Phemister's operation. While the results of both bone stimulation and sympathectomy are unpredictable, stapling may be controlled accurately and may be used to balance limb length. A combination of these procedures should produce almost exact equalization. I should warn again as I did in my paper, that the operation for removal of staples in itself constitutes bone stimulation.* Therefore, in both linear and angular deformities, slight overcorrection should be obtained before the staples are removed.

I have no explanation for the failure of bone-stimulation experiments in animals. In children, the fact of post-traumatic increase in length is well established, but the results are not predictable. After a fracture of the femur in a child between six and ten years of age, the average overgrowth is one centimeter. Sometimes the bone remains the same length. Sometimes the relative length is increased by as much as two or three centimeters. The result is apparently independent of the type of fracture or the distance from the epiphysis.

As Dr. Pease has stated, sometimes the tibia distal to the fractured femur will also overgrow. I have found one case in which the tibiae were measured accurately by means of x-rays prior to the fracture. In the six months following the fracture, the tibia on the affected side overgrew 1.1 centimeters. In most of the cases which I have checked, there has been no overgrowth.

Chronic osteomyelitis of the shaft of the femur will almost invariably produce acceleration of growth of the femur. In one such case, the tibia on the affected side overgrew 1.8 centimeters. In other cases with even more extensive osteomyelitis of the femur, the tibiae were of equal length.

This matter of "equalization" of limb length by nature is not a beneficent force but a matter of physiology. The rate of growth changes according to the conditions under which growth takes place. These conditions may be very complex.

The epiphysis of a bone which is stimulated by disease, fracture, or operation will usually close a few months prematurely. But in the last months during which the epiphyseal plate on the other side remains open, there is usually little, if any, growth.

I wonder that Dr. Pease did not stimulate the fibula in some of his cases. It is easy to arrest growth of the fibula at the proximal end according to Phemister's technique or to arrest growth temporarily by stapling. It should not be hard to stimulate its growth by implantation of an ivory screw.

Dr. Pease has made a real contribution in reviving our interest and in improving the technique of bone stimulation. I should like to thank him personally for a method which I shall use.

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Dr. A. R. Shands, Jr., Wilmington, Delaware: The problem of equalization of limb length has long presented a challenge to the orthopaedic surgeon. The procedures of shortening the long limb and lengthening the short limb have received a great deal of attention over the years, especially from such workers as Abbott, White, Phemister, Compere, and many others. Many different techniques have been described. No one method has been accepted because of various technical reasons and oftentimes serious complications. In 1933, when Dr. Phemister published his report on a method of equalizing limb length by destroying in whole or in part certain of the growth centers of the long bones, the procedure received ample criticism. The thought immediately presented itself: How can one tell how much future growth will take place at the particular epiphyseal plate being eradicated? Over the years so much information has been acquired that, through the work of Green, Barr, and others, it is now possible to predict reasonably well the amount of growth which can be expected from a certain epiphysis in the lower extremity in a child over the age of ten. The procedure has become firmly established and is performed more generally at the present time than any other for limb equalization in the growing child. Blount's procedure of stapling the epiphyses to prevent growth definitely has its place; but I do not believe it will ever be the complete answer to the problem.

The thought of stimulating growth in the epiphyses of the short leg as demonstrated in the work of Dr. Pease, of course, is not new. Twenty-five years ago I had a rather close association with Harold Bohlman when he was doing his work at the Children's Hospital School in Baltimore. Dr. Pease has cited his work which was on ninety-two guinea pigs in which twenty-two different materials or combinations of substances were placed in drill holes in and about or through the epiphyseal line. Bohlman's conclusions were, as Dr. Pease has stated, that the clinical and surgical use of foreign materials in the epiphyseal cartilage plate region to promote bone growth was not justified. Dr. Pease's approach in placing metal and ivory screws close to but not through the epiphyseal plate is new, so far as I know. It is quite likely that it does produce an increase in vascularity and that it accelerates growth up to a certain point. As the growth of the bone takes place, the epiphyseal line grows away from the foreign material. There are grave doubts in my mind as to whether the latter has any further value in producing accelerated growth. If each year these screws could be removed and then placed adjacent to the epiphyseal area until the termination of growth, I should think that the effect would be more striking. One wonders if this effect is not the same as that following obstruction of the medullary cavity which very often leads to compensatory increased circulation at the metaphyseal end of bone with overgrowth, such as is seen in osteomyelitis, over-riding fracture fragments, and occasionally non-union. I am told that Mr. Trueta, Professor of Orthopaedic Surgery at Oxford, has been very much interested in this problem and has expressed the opinion that bone growth may be stimulated by an artificial plugging of the medullary canal. It may be that this is exactly what the screws of Dr. Pease do temporarily.

The idea of plugging the medullary canal brings to mind the beautiful work of Urist, McLean, and their coworkers at the University of Chicago, which was reported at this meeting two years ago, on endosteal-bone formation in estrogen-treated mice. With these experiments they showed that the new deposits of intramedullary bone were largest at those points in the skeleton where most of the increase in length of the bones occurred during the period of growth. I reviewed Dr. Urist's work in preparing this discussion and I wonder if some of his estrogen-treated mice did not show more longitudinal growth of the long bones than would be expected in the normal mice of the same age.

For the last several years, I have been very much interested in endosteal-bone formation and I have done some preliminary studies with Dr. Earl W. Schafer. We have been working out a method of experimentally injecting a bone paste into the medullary cavity of a bone, thus replacing the marrow with this substance. Our work has only progressed to the point of developing a special metal syringe which can introduce a semisolid substance into the cavity under pressure.

Dr. Pease has said that this is only a preliminary study which may suggest or lead to something worth while. It is always interesting to hear new ideas presented, even though the results are not positive. No piece of experimental work or new method was ever tried which did not help us in the development of our thinking, especially in such complex problems as bone formation and bone growth. I congratulate Dr. Pease.

Dr. Pease (closing): I want to thank Dr. Blount and Dr. Shands for discussing this paper.

Many people who have children with disabled limbs on one side do not want them to have any operative

(Continued on page 63)

LEGG-PERTHES DISEASE

AN EVALUATION OF TREATMENT BY TRACTION AND ISCHIAL WEIGHT-BEARING BRACE*

BY CHARLES H. HERNDON, M.D., AND CLARENCE H. HEYMAN, M.D., CLEVELAND, OHIO

From Gates Hospital for Crippled Children, Elyria, and
University Hospitals, Cleveland

The purpose of this paper is to report upon a study of forty-one hips with Legg-Perthes disease uniformly treated by traction and a non-weight-bearing brace. The term "Legg-Perthes disease" is used because it applies to a definite clinical entity not to be confused with other conditions resembling it on the roentgenogram. Similar changes may occur, for example, in association with congenital dislocation of the hip, but the two conditions are not the same.

Although it is generally agreed that pressure on the head of the femur is harmful and that weight-bearing is to be avoided at least during the progressive phase of the disease, treatment differs remarkably both as to method and duration. Some believe it is essential to protect the hip from any weight-bearing until regeneration is complete. According to Danforth and Pike, this may require confinement to bed for as long as three to five years. Others subscribe to Legg's opinion that treatment does not influence the result. Most orthopaedic surgeons adopt a method somewhere between these extremes. Traction or recumbency, plaster spica casts, ischial weight-bearing braces, the leg sling, crutches used together with an elevated heel and sole on the shoe opposite the involved limb, or some other means of preventing or discouraging weight-bearing, all have their advocates. This wide divergence of opinion with respect to treatment of a relatively common orthopaedic problem has prompted the authors to evaluate their own clinical results and to record the roentgenographic results in an objective manner, in order to permit comparison with results of treatment by other methods.

While favoring a long period of constant traction in bed and enforced avoidance of weight-bearing, the authors are not convinced by their own observations of the utmost importance of these measures, and more openly question that the results of confinement to bed for three to five years are commensurate with the sacrifice. On the other hand, it would seem that more protection to the hip than that offered by a pair of crutches and an elevated shoe on the contralateral foot is indicated during the progressive phase of the disease in order to prevent weight-bearing on the presumably soft plastic head of the femur. If weight-bearing is harmful and leads to deformity, it should be prevented consistently and effectively.

In view of Danforth's unusually good results following treatment by bed rest and non-weight-bearing, traction in bed was adopted as the most efficient way of preventing the harmful effects of pressure on the femoral head during the active phase of the disease. We were later encouraged to continue this effort by Gill's report of favorable results following traction. Since constant supervision and restraint are necessary for traction and for assurance that the child will not bear weight on the involved extremity, hospitalization would be required for as long as three or four years. Aside from the expense of hospitalization, it was believed to be undesirable to take a child out of his home and away from his normal environment for so long a time for a condition which cannot be considered critical. A compromise was therefore adopted.

Treatment of all cases in this report consisted in traction in bed with the patient

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* Based on an exhibit at the Eighteenth Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 1951.

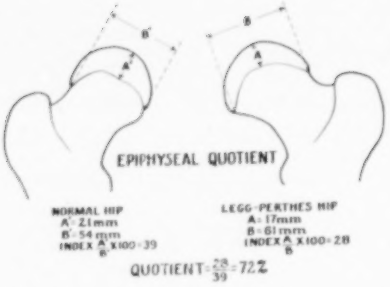
B'
A'
B
A
EPIPHYSEAL QUOTIENT
NORMAL HIP
A'=21mm
B'=54 mm
INDEX A'/B' X100=39
LEGG-PERTHES HIP
A=17mm
B=61mm
INDEX A/B X100=28
QUOTIENT=28/39=72%

Fig. 1-A

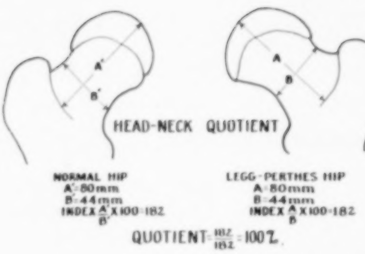
A'
B'
A
B
HEAD-NECK QUOTIENT
NORMAL HIP
A'=80mm
B'=44mm
INDEX A'/B' X100=182
LEGG-PERTHES HIP
A=80mm
B=44mm
INDEX A/B X100=182
QUOTIENT=182/182=100%.

Fig. 1-B

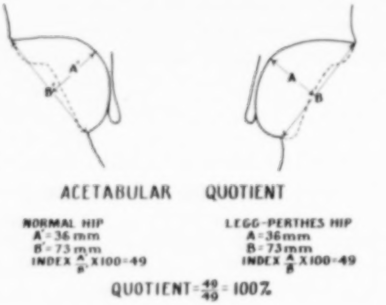
A'
B'
A
B
ACETABULAR QUOTIENT
NORMAL HIP
A'=36 mm
B'=73 mm
INDEX A'/B' X100=49
LEGG-PERTHES HIP
A=36mm
B=73mm
INDEX A/B X100=49
QUOTIENT=49/49=100%

Fig. 1-C

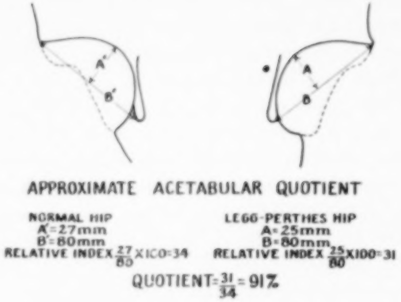
A'
B'
A
B
APPROXIMATE ACETABULAR QUOTIENT
NORMAL HIP
A'=27mm
B'=80mm
RELATIVE INDEX 27/80 X1C0=34
LEGG-PERTHES HIP
A=25mm
B=80mm
RELATIVE INDEX 25/80 X100=31
QUOTIENT=31/34=91%

Fig. 1-D

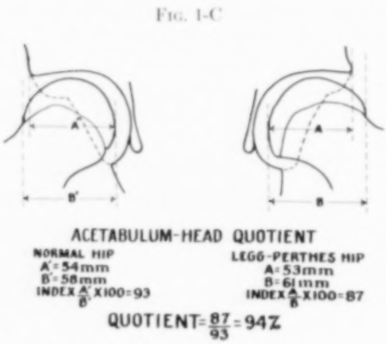
A'
B'
A
B
ACETABULUM-HEAD QUOTIENT
NORMAL HIP
A'=54mm
B'=58mm
INDEX A'/B' X100=93
LEGG-PERTHES HIP
A=53mm
B=61mm
INDEX A/B X100=87
QUOTIENT=87/93=94%

Fig. 1-E

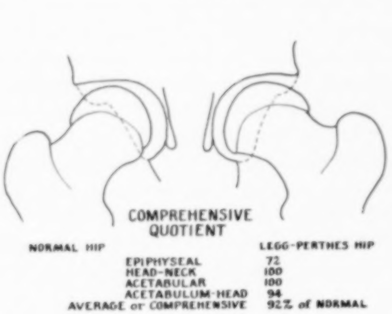
COMPREHENSIVE QUOTIENT
NORMAL HIP
LEGG-PERTHES HIP
EPIPHYSEAL 72
HEAD-NECK 100
ACETABULAR 100
ACETABULUM-HEAD 94
AVERAGE or COMPREHENSIVE 92% of NORMAL

Fig. 1-F

Figs. 1-A to 1-F: Comprehensive method of evaluating the roentgenographic end result. It should be noted that in measuring the acetabular quotient (Fig. 1-C) it is often difficult to visualize accurately the lower rim of the acetabulum; therefore the approximate acetabular quotient (Fig. 1-D) has been used in most cases as it has been found that it gives similar comparative values.

under complete control in a convalescent hospital until the roentgenograms showed beginning regeneration of the epiphysis. The patient was then allowed to become ambulatory, and, until regeneration was well advanced, the involved hip was protected by means of a Thomas ring traction brace, with an elevated shoe worn on the opposite side. A Thomas walking brace was then worn until it appeared certain that no further flattening of the epiphysis would occur.

Little difficulty is encountered in determining when the degenerative phase has come to an end and regeneration has begun. It is more difficult, however, to decide when regeneration has progressed sufficiently to justify discarding the brace and allowing

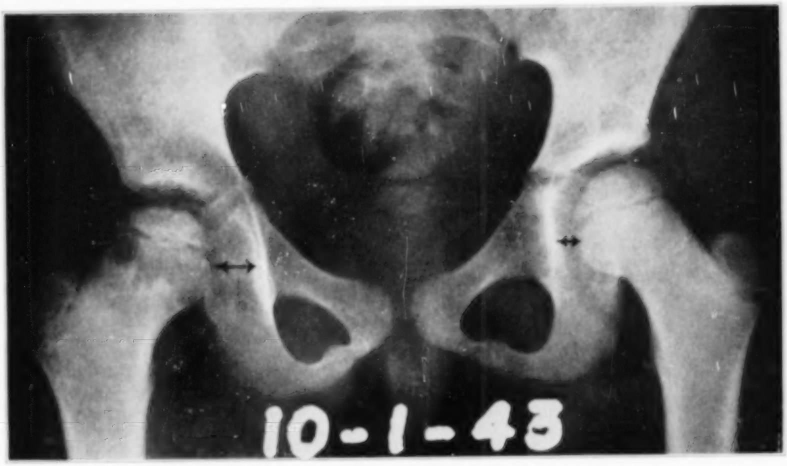

FIG. 2-A

October 1, 1943. Roentgenogram of an early case of Legg-Perthes disease. Waldenström's line measured 12 millimeters on the involved side and only 7 millimeters on the normal side. There was an increased clarity of the joint space compared with that in the normal hip.

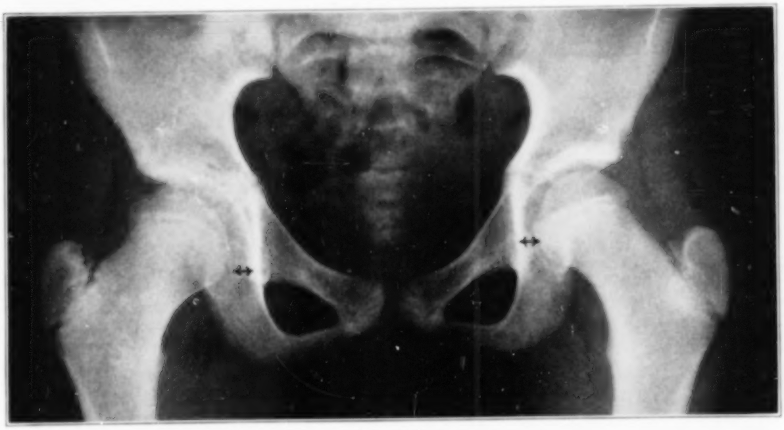

FIG. 2-B

December 3, 1948. Roentgenogram of same patient five years later demonstrating that Waldenström's line had returned to normal and that the joint space was comparable.

unprotected weight-bearing. Calcification must be adequate to prevent further collapse. In this series, however, unprotected weight-bearing was permitted before normal trabeculation of the epiphysis was restored entirely. It is believed that good cooperation was obtained in all cases, although there was, of course, no way of knowing whether some children did unprotected weight-bearing surreptitiously while they were ambulatory at home.

The average length of hospitalization with traction was 6.3 months, at a cost (according to present hospital rates) of about $1,800. Most of the patients were committed to the Crippled Children's Service of the Ohio Department of Public Welfare, which paid all expenses, and all were treated at Gates Hospital for Crippled Children, Elyria. The average duration of the disease was 3.5 years. Hospitalization for this length of time would

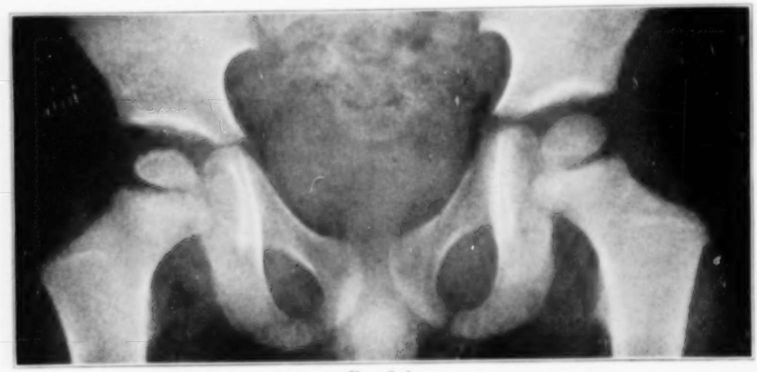

Fig. 3-A

Case D. S., child, four years old. Roentgenogram made at admission, January 8, 1937, eight months after onset of symptoms. Waldenström's line measured 11 millimeters on the right and 8 millimeters on the left. There was increased clarity of the joint space and slightly increased density of the femoral head. Traction in bed was begun immediately.

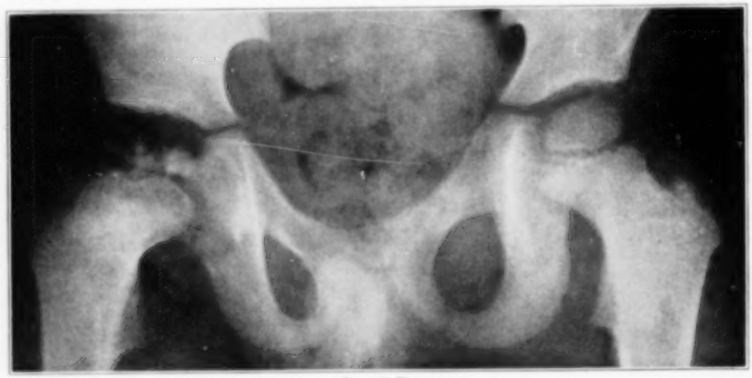

Fig. 3-B

October 25, 1937. Seventeen months after onset of symptoms. Marked fragmentation of the epiphysis had developed and rarefaction in the metaphysis next to the epiphyseal line was apparent. There was no evidence of recalcification. Traction in bed was continued.

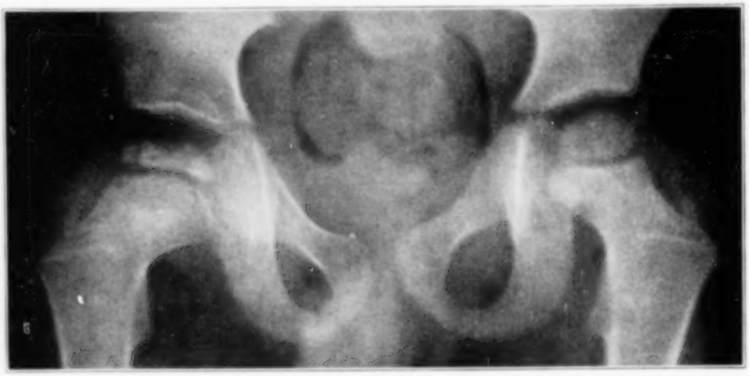

Fig. 3-C

January 29, 1938, twenty months after onset of symptoms. Note the distinct change which had occurred since the roentgenogram made three months previously. There was no further fragmentation, and there was spotty increased calcification in the epiphysis as well as in the metaphysis. Regeneration begins quite abruptly, and once it has begun, further fragmentation is rare.

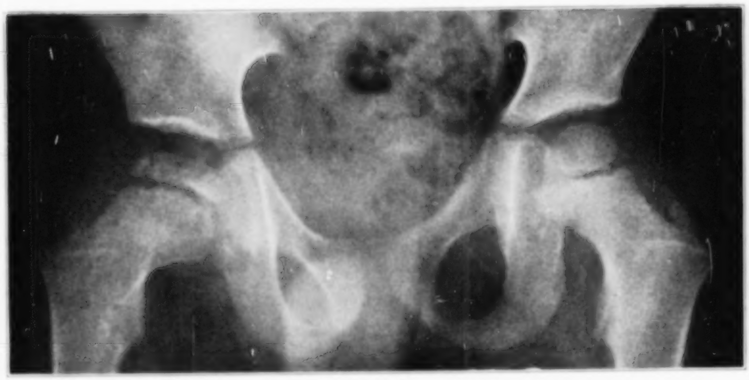

Fig. 3-D

April 18, 1938. There had been further progress in regeneration. The patient was allowed to become ambulatory with a Thomas extension brace.

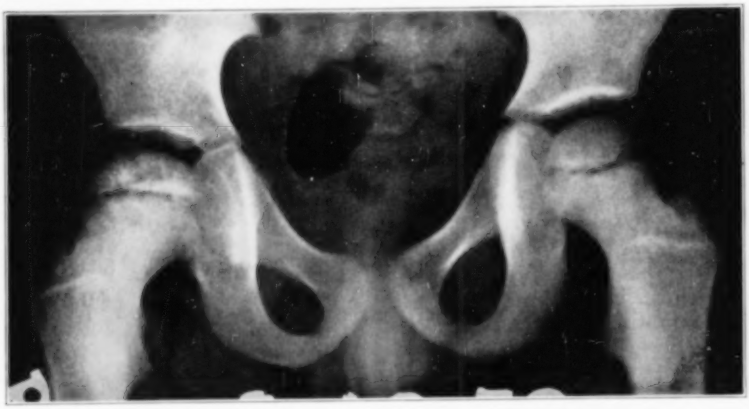

Fig. 3-E

May 19, 1939. Regeneration was progressing. At this time the brace was discarded and unprotected weight-bearing was allowed.

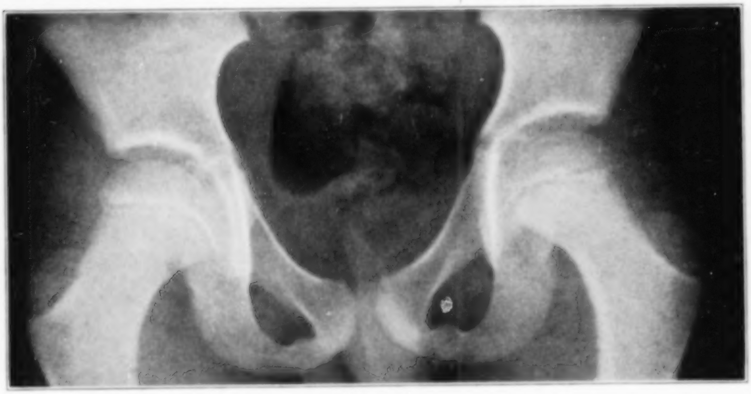

Fig. 3-F

September 5, 1941. Regeneration was found to be complete with normal bone trabeculation in the epiphysis and metaphysis.

have cost approximately $12,000, a prohibitive sum under the available facilities and scarcely justified by the results. The number of cases reported is not large, but since they were consecutive and treatment was uniform in all cases, it is believed to be large enough to indicate the results which may be expected from this method of treatment.

The writers do not advocate this method as being the best for all cases and certainly do not claim that traction and abstention from weight-bearing over an extended period of time will result in a normal hip. In fact, this study can show only what happens after treatment by traction and abstention from weight-bearing during the active phase of the disease. Perhaps the same results may be obtained by treatment which is less confining, but on the other hand the results might not be as good. Similar studies of late results in patients treated by other methods should certainly be made. For purposes of comparison, however, the roentgenographic results should be recorded by a method which takes into consideration all the components of deformity occurring in Legg-Perthes disease and

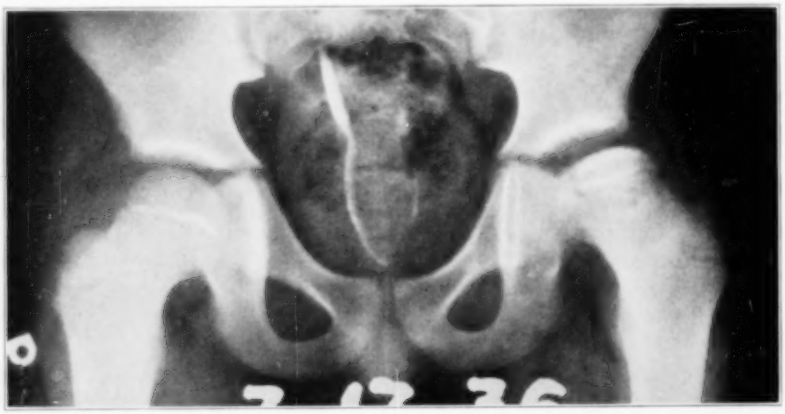

Fig. 4-A

Case J. F., child, eight years old. Roentgenogram made at initial examination, July 17, 1936, four months after onset of symptoms. Only minimal collapse had occurred, but there was marked increase in density of the capital epiphysis and moderate metaphyseal resorption. Traction was begun immediately.

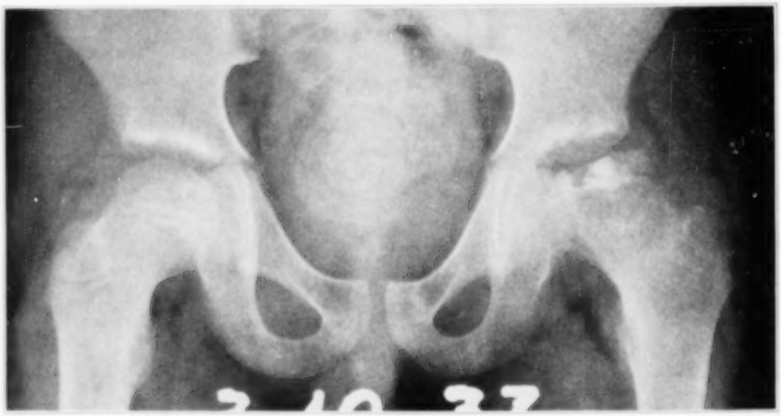

Fig. 4-B

March 10, 1937. Roentgenogram made eight months later. In spite of traction in recumbency under hospital control, severe collapse of the head had occurred. Regeneration was beginning and the patient was allowed to become ambulatory with a Thomas extension brace.

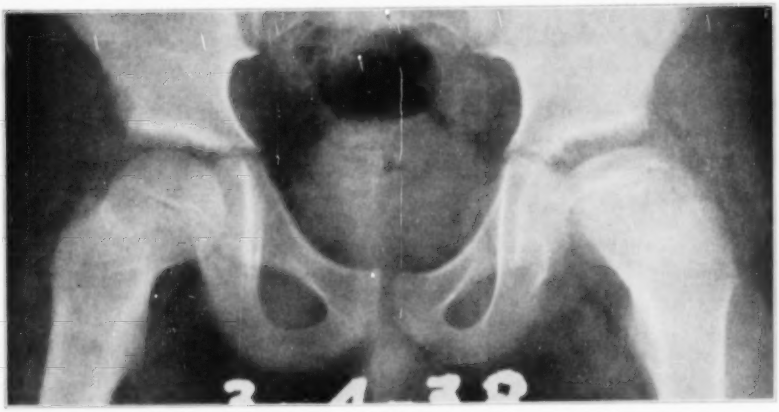

FIG. 4-C

March 4, 1938. The brace had been discarded and unprotected weight-bearing was allowed twenty-one months after onset.

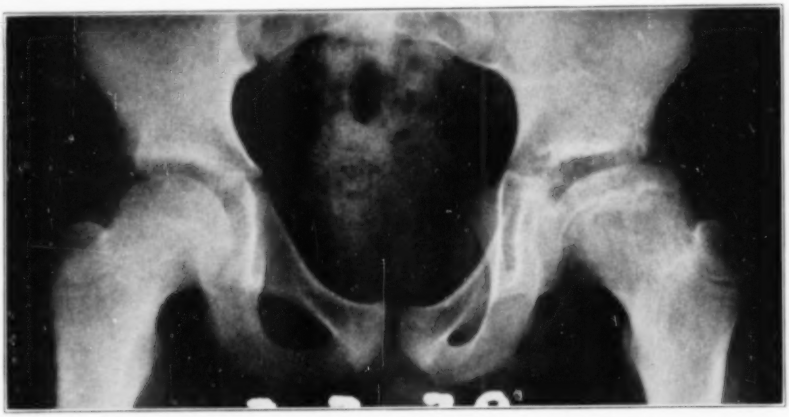

FIG. 4-D

March 3, 1939. Regeneration was complete thirty-six months after onset. There was no further collapse of the head after the patient was allowed to become ambulatory.

which records objectively and comprehensively all the roentgenographic characteristics of the involved as compared with the normal hip.

METHOD OF STUDY

In the course of this study it became apparent that a more accurate means of expressing the end-result evaluation than the conventional "normal", "good", "fair", and "poor" would be highly desirable and even essential to the value of the report. These conventional terms do not necessarily mean the same thing to different investigators, even if they are carefully qualified. It would be of great advantage if results could be classified impartially and objectively by independent observers, so that these results could be accurately compared. It was found that almost all the patients at the time of the end-result evaluation could be rated as "good" to "normal" on the basis of symptoms and physical findings. An attempt was therefore made to evaluate accurately the anatomical result as seen in the roentgenogram. The method consists in comparing the measurements of the important components of the deformity with measurements of corresponding components of the structure of the normal hip and expressing the result as a comprehensive quotient. In patients with bilateral involvement, of course, only an approximate estimation of the result is possible. There are four principal components of the abnormality which may affect the function of the hip in later life and which should be considered in evaluating the anatomical configuration of the articulation: The epiphysis is commonly flat and broad; the neck may be broad and short; the acetabulum may become more oblique and hence relatively broad and shallow; and an enlarged head may be inadequately covered by the supporting acetabular roof. Figures 1-A to 1-F indicate how these various components have been reduced to a measurable basis. The technique and evolution of this method of evaluation have been reported in detail in a previous publication.[6]

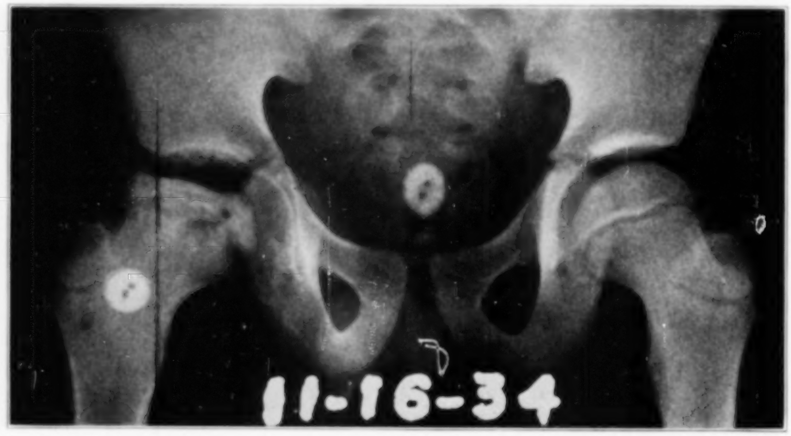

Fig. 5-A

Case J. J., child, nine years old. Roentgenogram made November 16, 1934, twelve months after onset of symptoms. Traction was begun at this time.

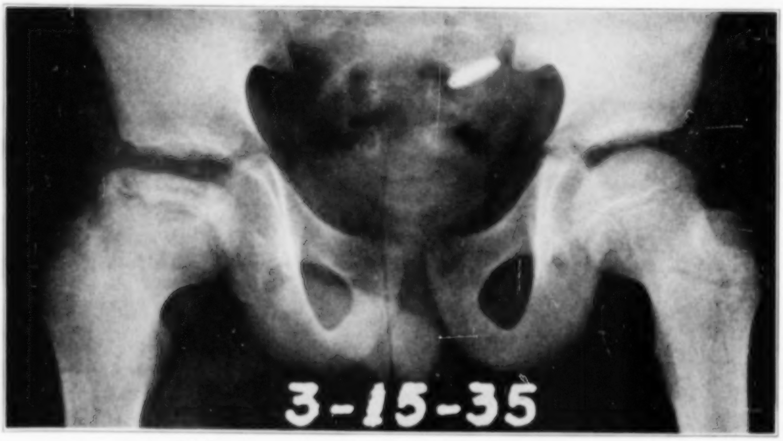

Fig. 5-B

March 15, 1935. There was beginning regeneration. The patient was allowed to become ambulatory with a Thomas extension brace.

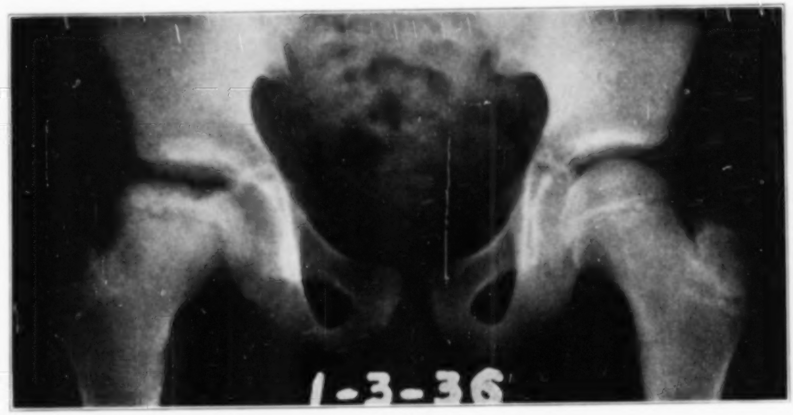

Fig. 5-C

January 3, 1936. The brace had been discontinued and unprotected weight-bearing was allowed twenty-two months after onset.

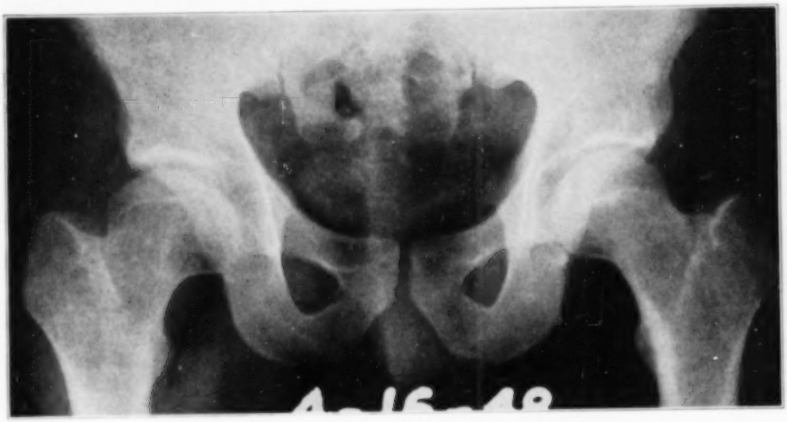

Fig. 5-D

April 16, 1948. Follow-up roentgenogram fourteen and one-half years after onset of symptoms, when the patient was twenty-three years old. Epiphyseal quotient, 54 per cent.; head-neck quotient, 79 per cent.; relative acetabular quotient, 78 per cent.; acetabular-head quotient, 85 per cent. Comprehensive quotient, 74 per cent. of normal.

EVALUATION OF RESULTS

A total of thirty-seven patients with forty-one hips involved have been followed for an average of 7.4 years. The patients' ages at onset of the disease ranged from three and one-half to eleven years, the average being 6.5 years. No unusual findings were noted in the clinical picture. Characteristically, the symptoms began insidiously with mild hip pain, limp, and limitation of motion. The average time between onset of symptoms and initial examination was 6.4 months, although some patients were seen quite early in the course of the disease. In three patients with bilateral involvement the disease developed in one hip while the patient was under treatment for Legg-Perthes disease of the contralateral hip. Only six of the forty-one patients attributed the onset of symptoms to trauma.

In serial roentgenograms the changes noted were similar to those described by Gill, Brailsford, and others. We are in agreement with Gill on the sequence of pathological changes as indicated by the roentgenogram. In patients seen very early, the first changes

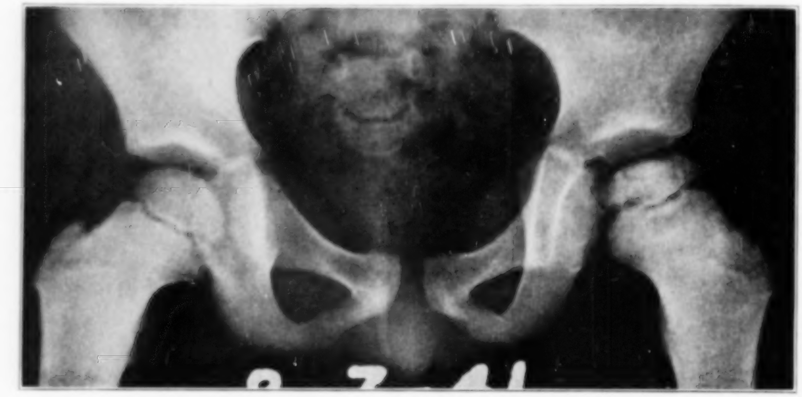

FIG. 6-A

Case P. K., child, five years old. Original roentgenogram made when traction was begun, February 7, 1941. The patient had been symptomatic for four months.

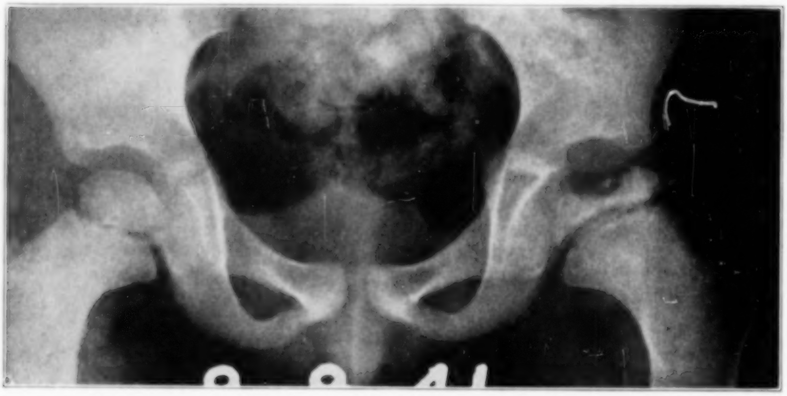

FIG. 6-B

September 9, 1941. Showing beginning regeneration.

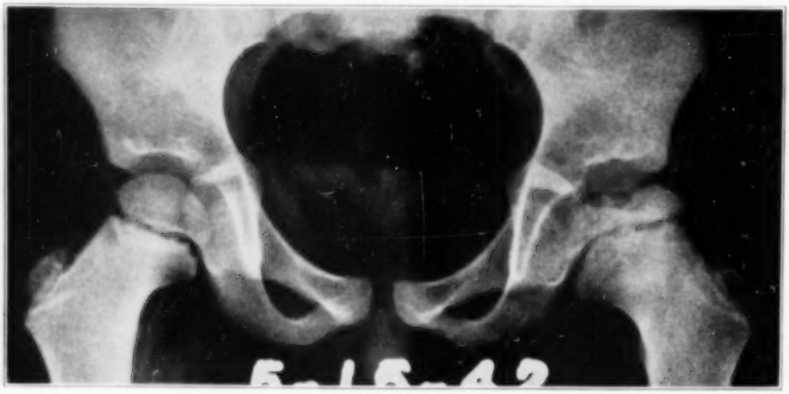

FIG. 6-C

May 15, 1942. Regeneration was progressing. Child was ambulatory, with Thomas extension brace started nineteen months after onset of symptoms.

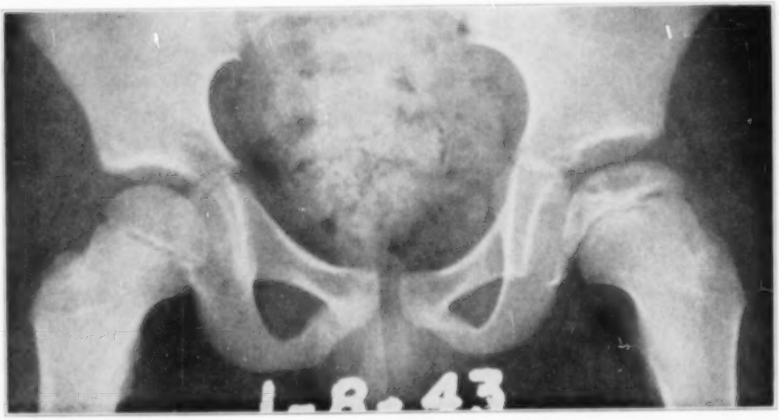

Fig. 6-D

January 8, 1943. Brace was discarded and unprotected weight-bearing was allowed twenty-seven months after onset.

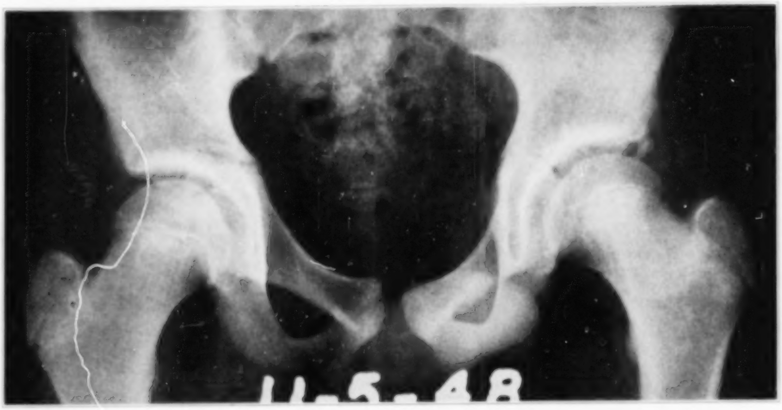

Fig. 6-E

November 5, 1948. Follow-up roentgenogram eight years after onset, when the patient was thirteen years old. Epiphyseal quotient, 72.7 per cent.; head-neck quotient, 100 per cent.; relative acetabular quotient, 100 per cent.; acetabular-head quotient, 100 per cent.; comprehensive quotient, 93.7 per cent. of normal.

noted were an increase in the length of Waldenström's line, when compared with the normal hip, and an increased clarity of the joint space (Fig. 2-A). The relative increase in Waldenström's line and the increased clarity of the joint space persisted throughout the disease but gradually returned to normal during the regenerative phase. A comparison of the vertical joint space and the vertical distance from the acetabular roof to the epiphyseal line of the involved hip with corresponding measurements of the normal hip yielded equivocal results and did not establish the true thickness of the radiolucent head, which in many cases is actually thicker than it appears to be in the roentgenogram.

At a variable period of time after onset of symptoms, usually within two to three months, a line of diminished density appeared in the metaphysis next to the epiphyseal line. Concomitantly, there was a relative increase in density of the femoral capital epiphysis. The characteristic sequence of metaphyseal resorption and fragmentation of the dense-appearing femoral head followed (Fig. 3-B). This period of fragmentation persisted

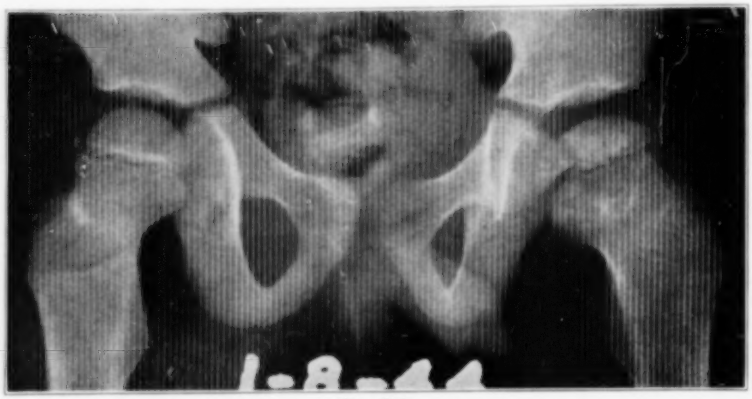

FIG. 7-A

Case D. A., child, seven years old. Original roentgenogram made at the time traction was begun, January 8, 1944. Duration of symptoms prior to treatment, three months.

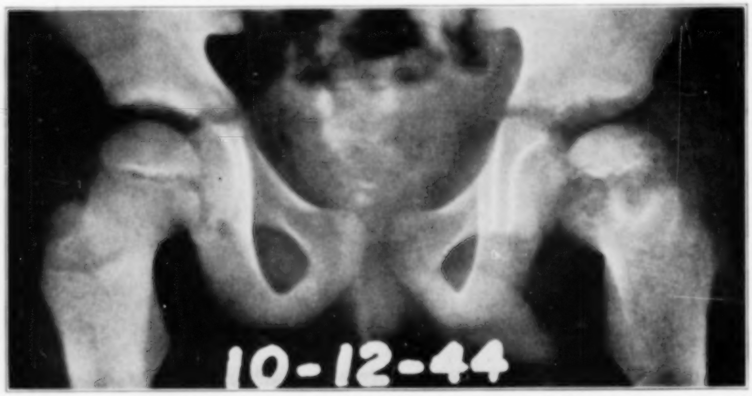

FIG. 7-B

October 12, 1944. Severe metaphyseal rarefaction with increased density of epiphysis. Traction in bed was continued.

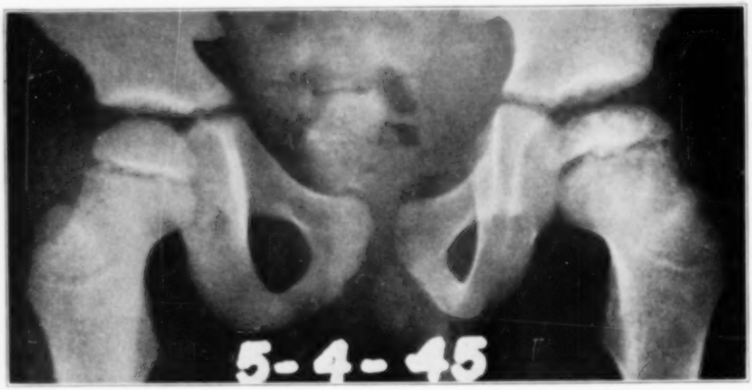

FIG. 7-C

May 4, 1945. Regeneration was beginning. Child was allowed to become ambulatory with Thomas extension brace.

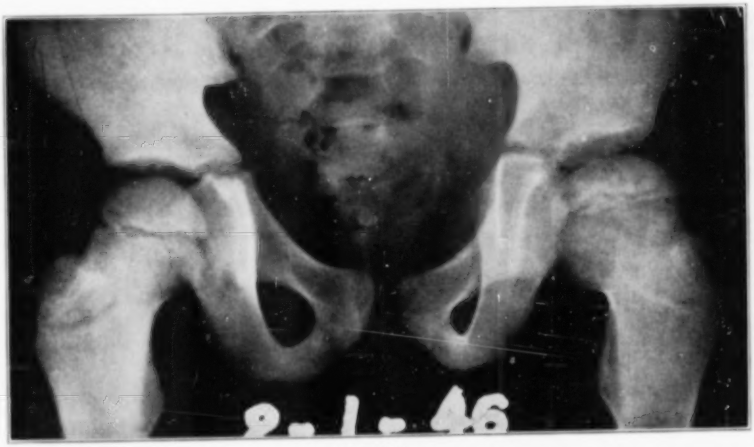

FIG. 7-D

February 1, 1946. Regeneration was progressing. Brace was discarded and unprotected weight-bearing was allowed twenty months after onset of symptoms.

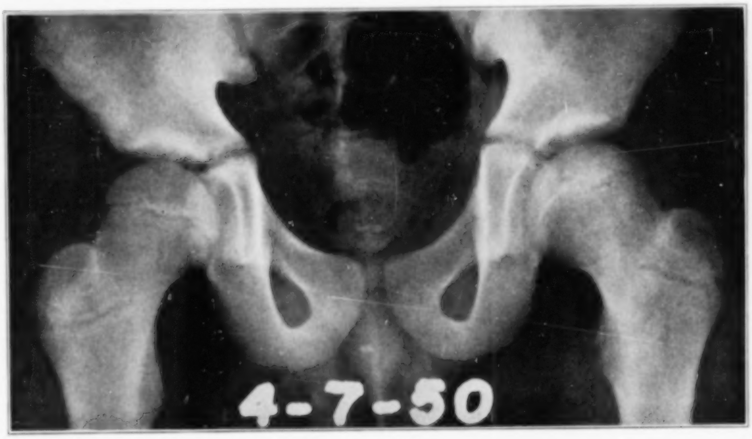

FIG. 7-E

April 7, 1950. Follow-up roentgenogram, six years and three months after onset. At this time the patient was thirteen years old. Epiphyseal quotient was 64.4 per cent.; head-neck quotient, 91.2 per cent.; relative acetabular quotient, 82.9 per cent.; acetabular-head quotient, 97.5 per cent.; comprehensive quotient, 86 per cent. of normal.

for an average of 14.5 months and it was during this phase of the disease that most of the residual deformity of the epiphysis developed. This was true even during treatment by traction in recumbency maintained during this period (Figs. 4-A to 4-D).

In studying the serial roentgenograms, it was found that at a particular point in the disease a rather abrupt change took place. X-rays were made at intervals of two to three months and it was apparent from one x-ray to another that there was no further fragmentation or degeneration and that there was beginning recalcification in the metaphysis and in the radiolucent areas of the capital epiphysis, indicating the end of the stage of fragmentation and the beginning of the regenerative phase of the disease (Fig. 3-C). The average time between the beginning of the regenerative process and the reestablishment of normal trabeculation was 27.8 months.

An unexpected but significant observation was that once regeneration was well under way, no further collapse in the head of the femur occurred, even though unprotected weight-bearing was allowed (Figs. 5-A to 6-E). Thus we found some justification for our compromise method of treatment,—that is, as complete protection of the femoral epiphysis as possible during the progressive phase of the disease, but resumption of unprotected weight-bearing before normal trabeculation has been restored. In none of these cases was a premature or asymmetrical fusion of the epiphyseal line observed. Any shortening of the extremity that occurred could be accounted for by the flattening of the head and neck of the femur. The maximum amount of shortening observed was one-half inch. The angle of the neck with the shaft of the femur on the affected side was compared with that on the normal side. Coxa valga occurred about as frequently as coxa vara, while the angle was essentially the same in most cases. In the early stages of the disease, the acetabulum was normal in all cases. The acetabular changes appearing later in deformed hips were adap-

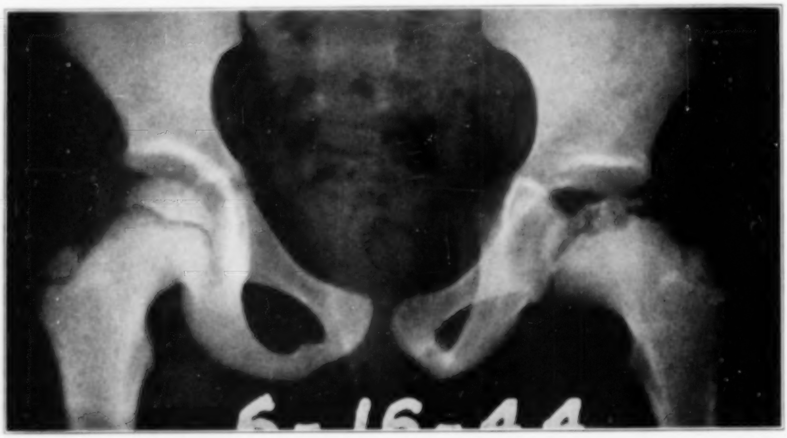

Fig. 8-A

Case P. C., child, five years old. Original roentgenogram made at the time traction was begun, June 16, 1944. Duration of symptoms prior to treatment, eighteen months.

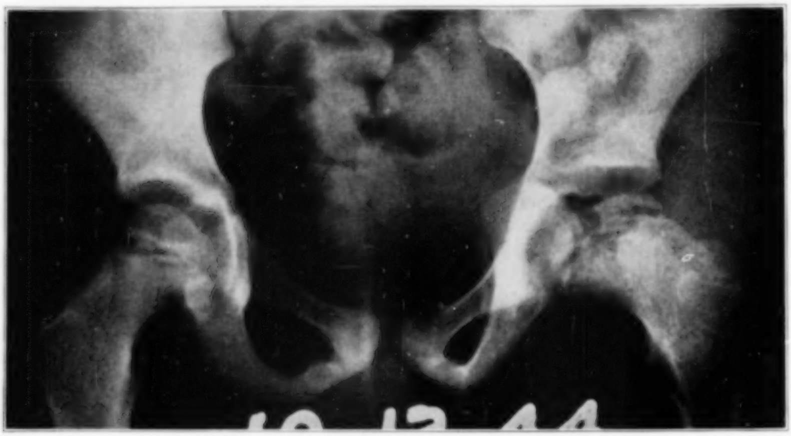

Fig. 8-B

October 12, 1944. Beginning regeneration. Child became ambulatory with a Thomas extension brace.

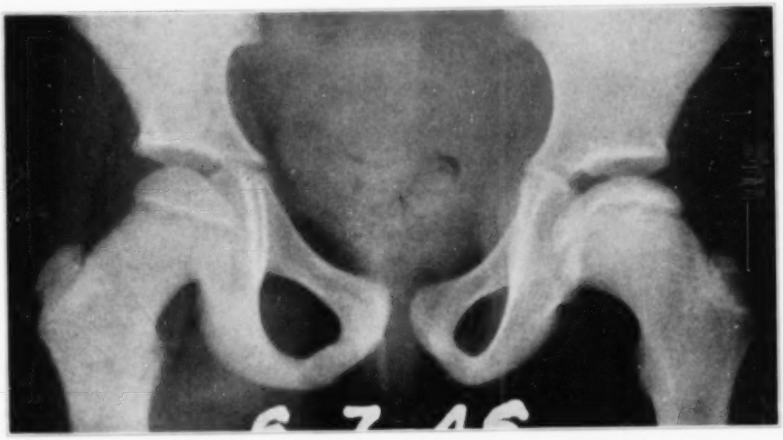

FIG. 8-C

June 7, 1946. Brace was discarded and unprotected weight-bearing was allowed forty-one months after onset of symptoms and twenty-three months after treatment had been started.

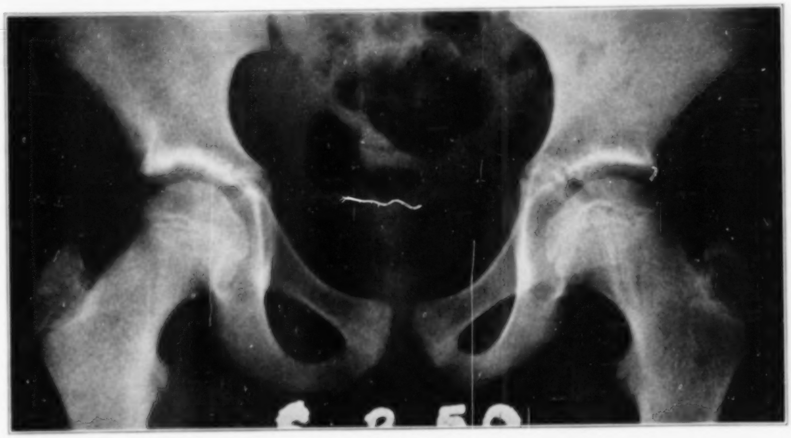

FIG. 8-D

June 2, 1950, seven and one-half years after onset. At this time the patient was thirteen years old. Epiphyseal quotient, 57 per cent.; head-neck quotient, 86 per cent.; relative acetabular quotient, 85 per cent.; acetabular-head quotient, 85 per cent.; comprehensive quotient, 78 per cent. of normal.

tive, secondary to the change in the shape of the femoral head.

As noted above, all patients were treated initially by bed rest on a Bradford frame with Buck's extension traction applied to the affected extremity. This was maintained until there was a reversal of the process of absorption and fragmentation toward regeneration. The time required for this was an average of 6.3 months under traction, or 12.7 months after onset of symptoms. Ambulation was then started with the protection of a Thomas ring traction brace on the affected limb and a built-up shoe on the opposite side. Seventeen of the forty-one hips were still in a stage of fragmentation and twenty-four were in a more advanced stage of regeneration at the time ambulation with a brace was started. The traction brace was maintained for an average of 5.8 months and was then changed to a Thomas caliper brace with an ordinary shoe on the opposite side. This brace

TABLE I

CONVENTIONAL CLINICAL END-RESULT EVALUATION OF FORTY-ONE HIPS AFFECTED BY LEGG-PERTHES DISEASE

Evaluation	Normal	Good	Fair	Poor
By Patient	36	4	1	0
By Surgeon	12	21	4	4

was maintained for an average of 5.6 months longer. Weight-bearing without protection was allowed at an average of 23.5 months after onset of the disease. At that time, four hips were still in a phase of fragmentation, thirty-five were in the reconstructive phase, and two were healed.

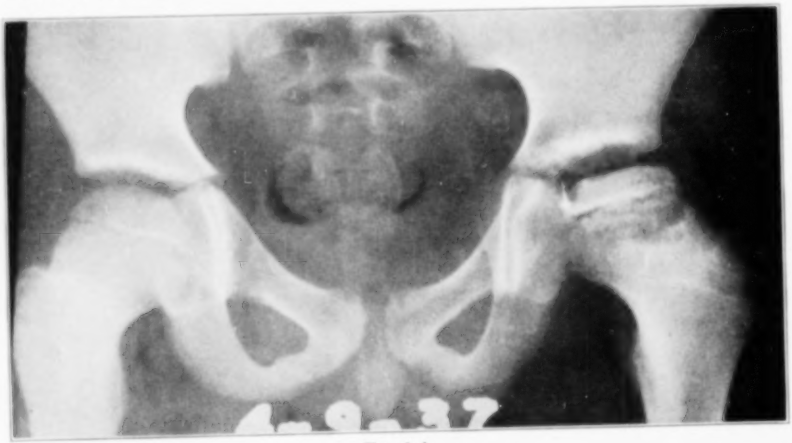

FIG. 9-A

Case R. W., child, eight years old. Original roentgenogram made April 9, 1937, at the time when traction was begun. Duration of symptoms prior to treatment, nine months. Note severe metaphyseal resorption.

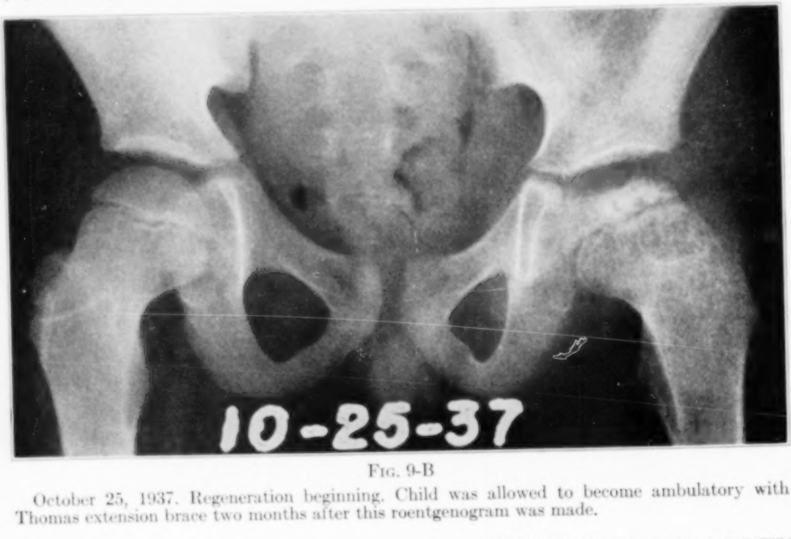

FIG. 9-B

October 25, 1937. Regeneration beginning. Child was allowed to become ambulatory with Thomas extension brace two months after this roentgenogram was made.

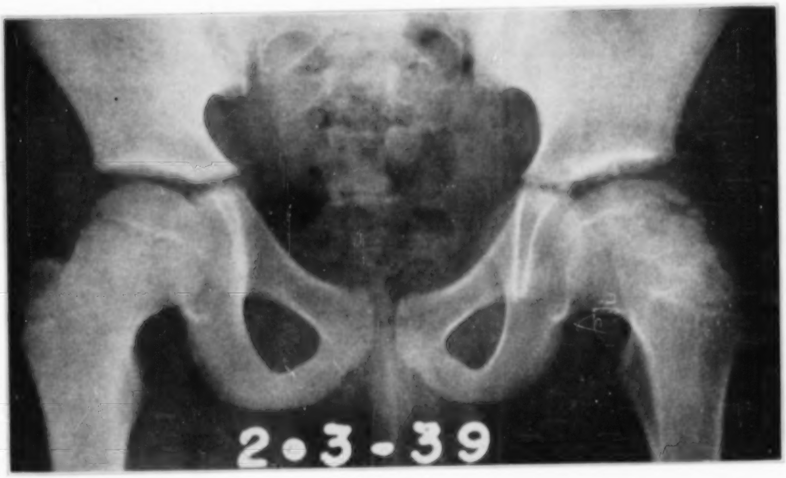

Fig. 9-C

February 3, 1939. Brace was discarded and unprotected weight-bearing was allowed thirty months after onset. Regeneration was progressing.

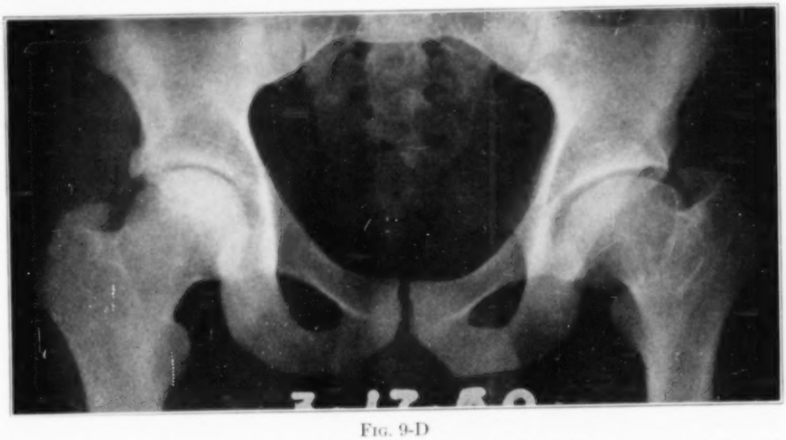

Fig. 9-D

March 17, 1950, thirteen and one-half years after onset. At this time the patient was twenty-one years old. Epiphyseal quotient, 55.3 per cent.; head-neck quotient, 72 per cent.; relative acetabular quotient, 78.5 per cent.; acetabular-head quotient, 94.8 per cent.; comprehensive quotient, 75.2 per cent. normal.

At the end-result physical examination only four patients of the thirty-seven had a limp and three complained of pain in the affected hip after strenuous exercise. Twenty-eight had a normal range of motion in the involved as compared with the sound hip. Three had limited abduction; one had slight limitation of flexion; two had limited extension; five had limited internal rotation, and nine had slight limitation of external rotation. The limitation of motion was minor in all cases and caused no functional difficulty. In only one case had the disability influenced the patient's occupation.

Conventional ratings of the clinical or functional result were based on both the patient's and the surgeon's estimates. Thirty-six of the affected hips were considered by the patients to be as good as the normal. Four thought the result was good, but reported some restriction of motion or occasional pain; and one patient had symptoms so severe that he

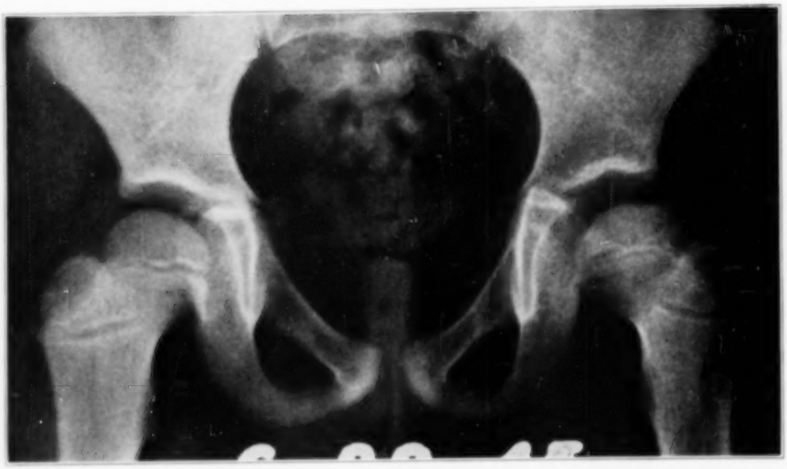

Fig. 10-A

Case M. H., a child, five years old. Original roentgenogram made June 29, 1945, at the time traction was begun. Duration of symptoms prior to treatment, two months.

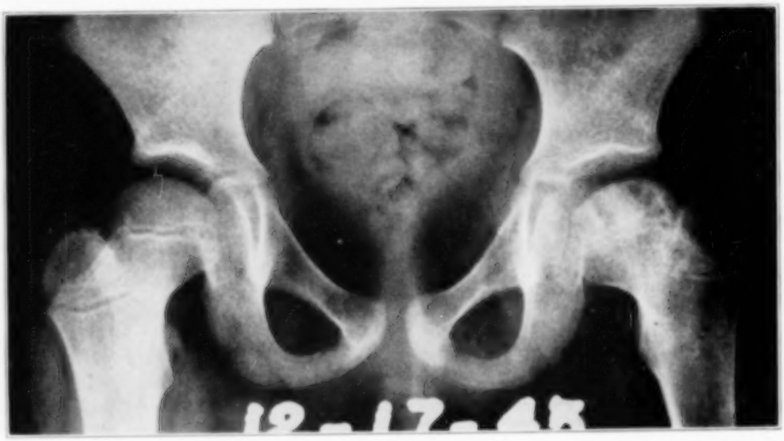

Fig. 10-B

December 17, 1945. Beginning regeneration. Child became ambulatory with Thomas extension brace.

TABLE II

Comparison of Conventional Evaluation of Roentgenographic Results with the Comprehensive Method of Evaluation Used in This Study *

No. of Cases	Per cent. of Series	Conventional Evaluation	Comprehensive Method (*Per cent. of Normal*)
9	27.3	Excellent to Normal	90 to 100
11	33.3	Good	80 to 90
13	39.4	Fair	70 to 80
0	0	Poor	60 to 70
0	0	Bad	Below 60

* Cases with bilateral involvement not included.

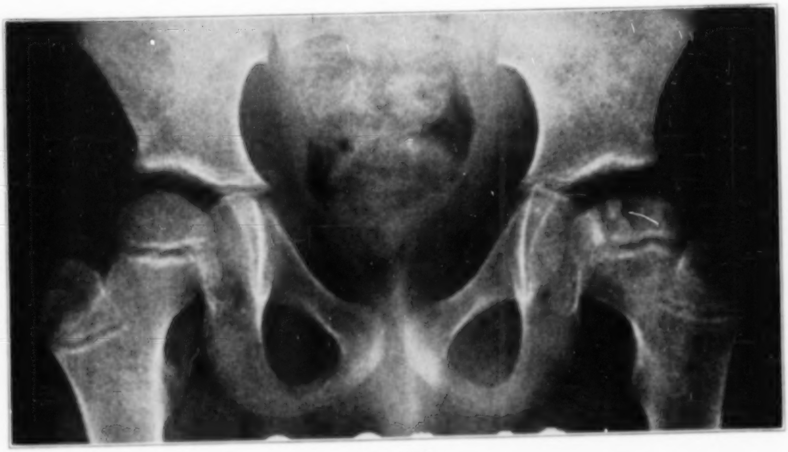

FIG. 10-C

February 21, 1946. Regeneration was progressing. Brace was discarded and unprotected weight-bearing was allowed.

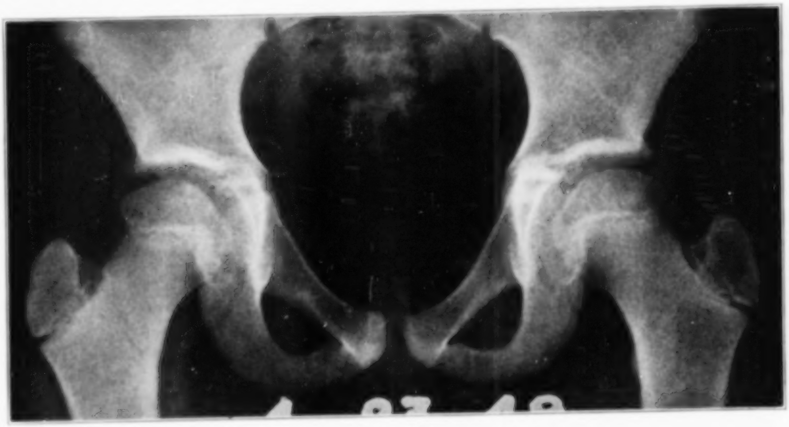

FIG. 10-D

April 23, 1949, four years after onset. At this time the patient was nine years old. Epiphyseal quotient, 94.8 per cent.; head-neck quotient, 83.1 per cent.; relative acetabular quotient, 90.7 per cent.; acetabular-head quotient, 100 per cent.; comprehensive quotient, 92.6 per cent. of normal.

TABLE III

COMPARISON OF END-RESULT EVALUATIONS OF THIRTY-THREE CASES OF LEGG-PERTHES DISEASE IN TWO AGE GROUPS*

Age	70-75 Per cent.	75-80 Per cent.	80-85 Per cent.	85-90 Per cent.	90-95 Per cent.	95-100 Per cent.
Five Years or Younger		1	2	1	6	
Over Five Years	5	7	7	1	2	1

* Cases with bilateral involvement not included.

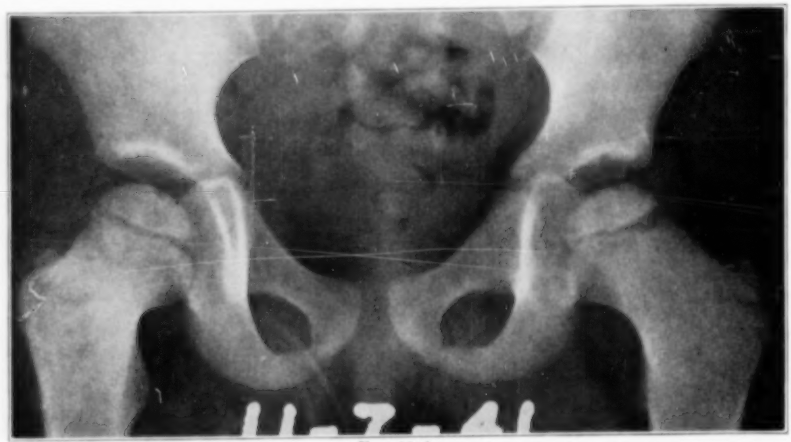

Fig. 11-A

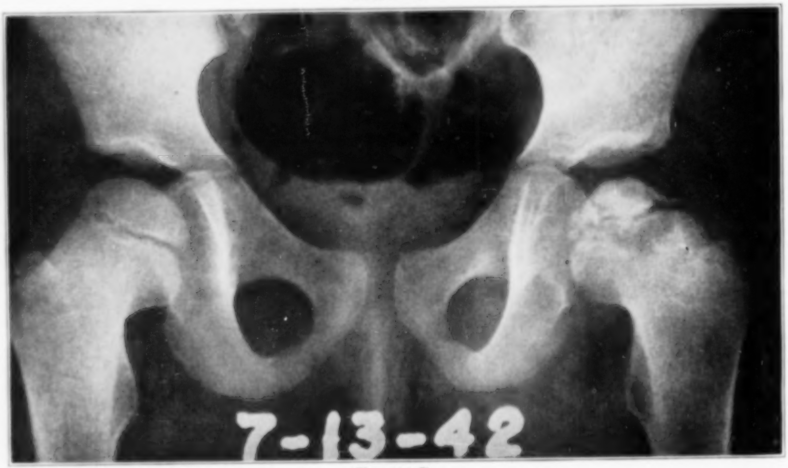

Fig. 11-B

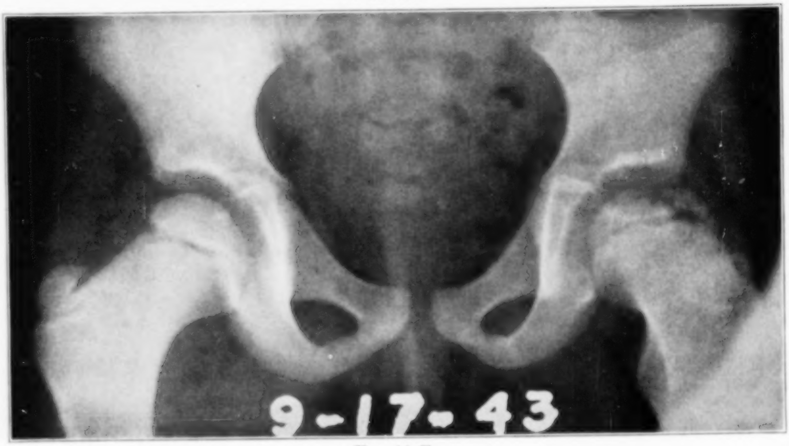

Fig. 11-C

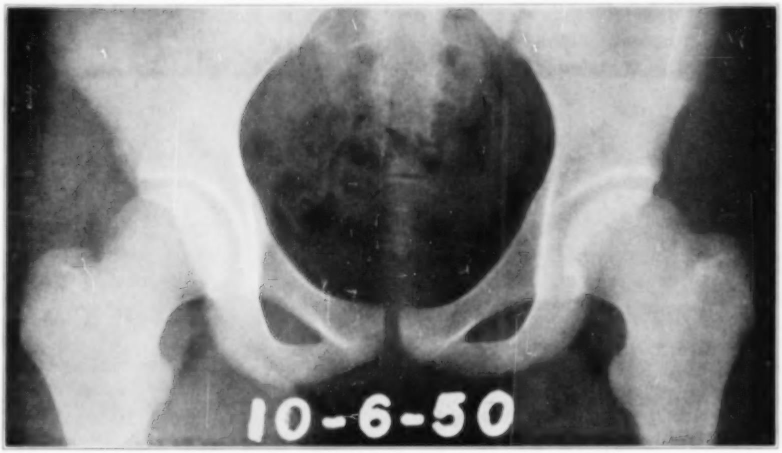

Fig. 11-D

Fig. 11-A: Case T. D., child, four years old. Original roentgenogram, made November 7, 1941, at the time traction was begun. Duration of symptoms prior to treatment, one month.

Fig. 11-B: July 13, 1942. Increased metaphyseal resorption and fragmentation of the epiphysis. Child was allowed to become ambulatory with Thomas extension brace.

Fig. 11-C: September 17, 1943. Beginning regeneration. Brace was discarded and unprotected weight-bearing was allowed twenty-three months after onset.

Fig. 11-D: Follow-up roentgenogram made October 6, 1950, nine years after onset. At this time the patient was thirteen years old. Epiphyseal quotient, 60 per cent.; head-neck quotient, 88 per cent.; relative acetabular quotient, 100 per cent.; acetabular-head quotient, 86 per cent.; comprehensive quotient, 83.5 per cent. of normal.

had to change his occupation. Conventional ratings as determined by the examiner were normal, twelve; good, twenty-one; fair, four; poor, four (Table I).

When the components of deformity were reduced to a measurable basis by establishing the comprehensive quotient, it was found that the average epiphyseal quotient* was 66.9 (lowest 47.7 and highest 100). The average head-neck quotient was 85.7 (lowest 72 and highest 100). The average relative acetabular quotient was 88.6 (lowest 70 and highest 100). The average acetabular head coverage quotient was 89.3 (lowest 73 and highest 100). The average comprehensive quotient was 82.8 per cent. of normal (lowest 71 per cent. of normal and highest 98.1 per cent. of normal). By this critical method of analysis, nine hips had a comprehensive rating of between 90 and 100 per cent. of normal; eleven between 80 and 90 per cent. of normal, and thirteen between 70 and 80 per cent. of normal. A comprehensive quotient of 90 to 100 per cent. of normal indicates an excellent to normal hip (Fig. 6-E); 80 to 90 per cent. of normal indicates a good hip (Fig. 7-E); 70 to 80 per cent. of normal, a fair hip (Fig. 8-D); 60 to 70 per cent. of normal, a poor hip, and below 60 per cent., a bad hip. In no patient treated by the method described was the comprehensive roentgenographic result below 70 per cent. In other words, there were no poor or bad roentgenographic results according to this method of analysis, which we believe is a rigidly severe one (Table II).

An attempt was made to analyze our data to determine, if possible, why some patients have an excellent result while others receiving the same treatment have only a fair result. If the patient is not seen until late and the deformity of the head is severe before treatment is started, one would not expect a good result. Generally this was true, but there were cases in which, in spite of a severe initial deformity, the result was good with comparatively little flattening of the epiphysis (Figs. 8-A to 8-D). Others who were seen early with minimal deformity progressed to a marked deformity with only a fair result (Figs. 4-A to 4-D). Marked individual differences in the disease process were observed and it is believed that this is probably the most important factor which influences the end result.

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* A full account of methods of measurement, and a definition of this and the following terms, have been given in a previous publication[6].

It was found that a more serious deformity necessitating a longer period of regeneration usually resulted in those cases showing extensive early rarefaction in the metaphysis (Figs. 9-A to 9-D) and that a less severe process could be anticipated if the metaphysis were not severely affected (Fig. 10-A to 10-D). This did not hold true in all cases, however, and could not be accepted as a reliable finding of prognostic significance. The only factor of real prognostic importance was the age of the patient. It was found, with few exceptions, that the older the patient, the worse the end result (Figs. 4-A to 4-D and 9-A to 9-D), and the younger the patient, the better the result (Figs. 6-A to 6-E, 10-A to 10-D, 11-A to 11-D, and Table III).

SUMMARY

Forty-one hips with Legg-Perthes disease have been studied clinically and roentgenographically after an average follow-up period of 7.4 years. All were treated uniformly by traction until there was a turning point toward regeneration, and after that with a non-weight-bearing traction brace until regeneration was well advanced. In determining the roentgenographic end-result rating of these cases, an objective method of estimation and recording was used, in which various components of the deformity were reduced to a measurable basis. The authors do not necessarily advocate the method of treatment employed in this series, but have attempted to show as accurately as possible what may be expected when this method of treatment is used. It is hoped that accurate comparison of different methods of treatment will be made by objective techniques of evaluation.

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PROPHYLAXIS OF SCOLIOSIS *

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Scoliosis or lateral curvature of the spine may be divided into two main types. *Structural scoliosis* is accompanied by wedging and other deformation of the vertebrae. *Functional scoliosis* is lateral curvature unaccompanied by such deformity of bone; in this case, since something must yield, curvature is accompanied by wedging of the discs. Such a functional curve (most often merely a postural defect) may be corrected by lateral pressure or by voluntary effort, but the spine will slump back as before when the correcting force is removed.

Structural scoliosis may be divided into congenital types, such as hemivertebra, and acquired types, and the latter may be further subdivided into two main groups, depending on whether the etiology is known or unknown:

(1) Those of known and obvious etiology, due to pronounced inequalities of soft-tissue tensions in the right and left sides of the body. Beyond the fact that postpoliomyelitic, postempyematic, and post-thoracoplastic types fall into this category, and that it includes a very small proportion of all cases of scoliosis, no further mention of this type will be made in the present paper.

(2) All others, hereinafter called "idiopathic".

This paper is concerned with a method of prophylaxis of a certain common type of scoliosis falling into the idiopathic group.

The principal characteristic of structural scoliosis, and the characteristic which makes it so difficult to treat, is its tendency to become progressively worse so long as growth continues. Like a candle in the heat, the growing spine, once deviated, will continue to sag and buckle. When growth ends progression stops, leaving the spine frozen in the position of deformity without change thenceforth.

Neither the candle nor the spine, however, will buckle if placed in recumbency. Thus scoliosis does not develop in the horizontal spines of quadrupeds (fowl, being bipeds, are afflicted with the condition [6]), and recumbency arrests the progress of the disease in the child [5].

The basis for this phenomenon is found in the fact that pressure arrests epiphyseal growth. This ancient principle, used by the Chinese in producing bound-foot deformities, finds its modern expression in the stapling of Blount in which epiphyseal growth is arrested through pressure produced by a metallic staple. Growth is resumed when the staple is removed.

The application of this principle to scoliosis is illustrated in Figures 1, 2, and 3. The vertical spinal column of all bipeds is continually being compressed by the action of gravity. So long as the spine is straight, as viewed from the front, the pressure of weight-bearing is evenly distributed between the right and left halves of each growing vertebral epiphyseal plate (Fig. 1). Hence any growth arrest due to pressure induced by gravity will be symmetrical, and no lateral deviation due to unequal growth will occur.

On the other hand, a functional curvature inevitably produces an asymmetrical distribution of gravitational pressure in the right and left halves of the upright spine (Fig. 2), and considerable compression may develop in the concavity of the curve [2]. The vertebral bodies which are unequally compressed will grow unequally†, yielding in time the wedged vertebrae of structural scoliosis (Fig. 3).

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* Based in part upon an exhibit at the Graduate Fortnight of the New York Academy of Medicine, October 1950.

† According to Lovett, certain factors such as rickets may facilitate the progression of structural changes in a functional curve. Risser has also emphasized the effect of nutritional factors. Perhaps heredity plays a similar role. These factors cannot in themselves initiate a curve, but they may act as factors predisposing to structural scoliosis. When more is known about them they may become important in the prophylaxis of structural curves.

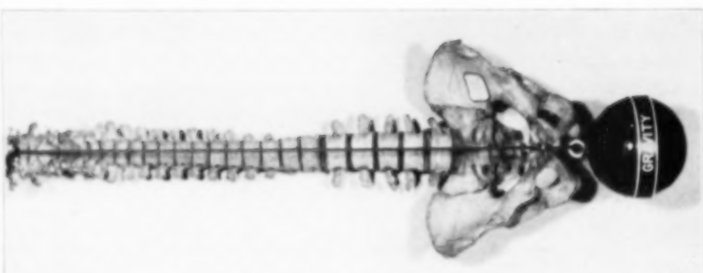

Fig. 1

In a straight spine the superincumbent weight falls equally on each side of the growing vertebral plate.

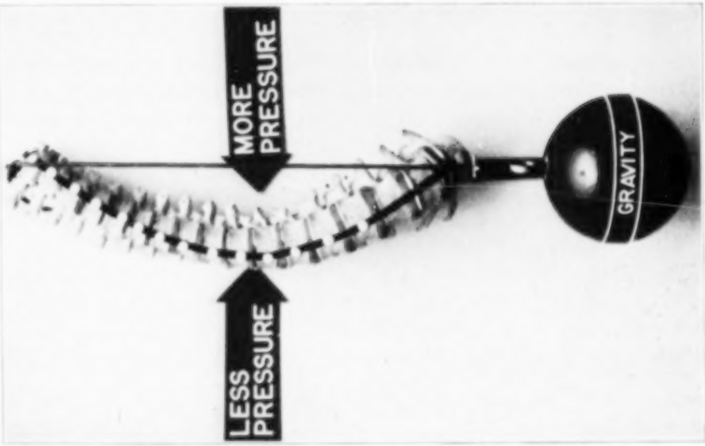
LESS PRESSURE
MORE PRESSURE
GRAVITY

Fig. 2

In a curved spine the superincumbent weight falls unequally on each side of the growing vertebral body. More pressure falls upon the side in the concavity of the curve. Hence growth on this side will be inhibited.

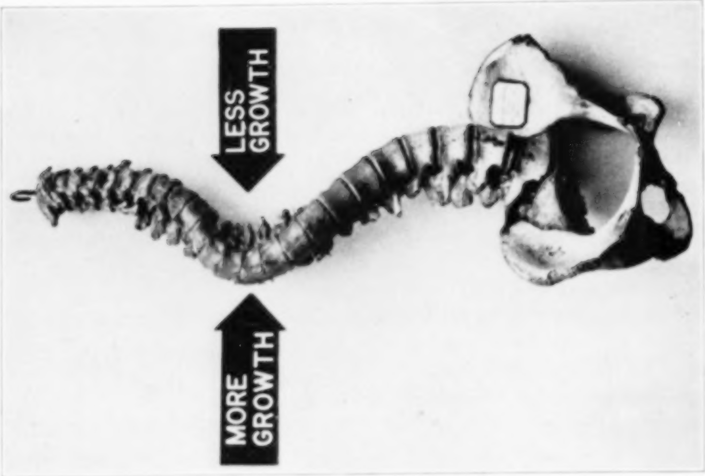
MORE GROWTH
LESS GROWTH

Fig. 3

The end result of unequal pressures is unequal growth—structural (wedged) scoliosis.

It should be noted that structural scoliosis may develop and progress solely by the action of gravity upon a functional curve, without preceding muscle weakness or soft-

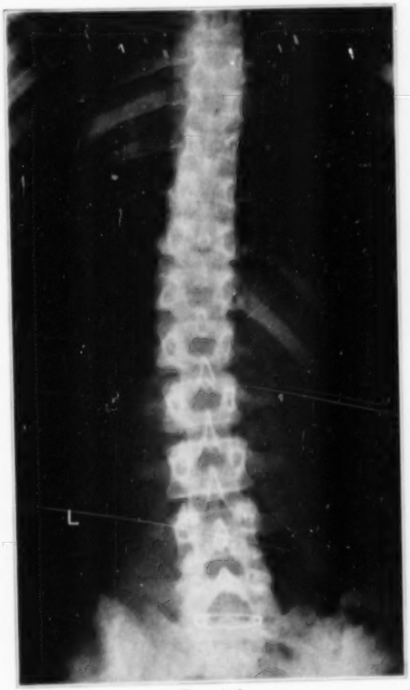

Fig. 4-A

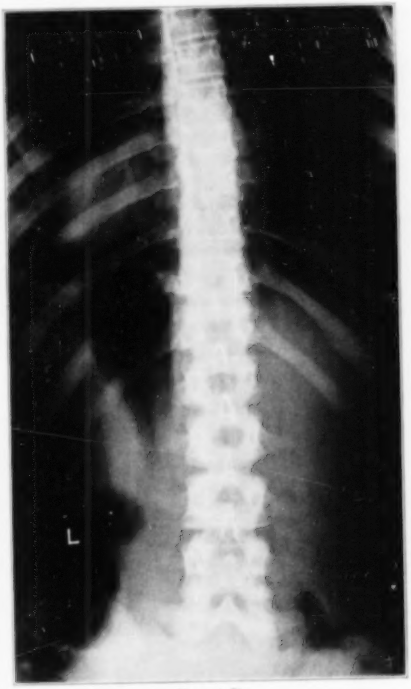

Fig. 4-B

Fig. 4-A: Left total functional scoliosis in a fourteen-year-old girl. The patient is standing erect.
Fig. 4-B: Same patient as in Fig. 4-A, standing with a lift of one and a half inches under the left heel. The curve is slightly overcorrected.

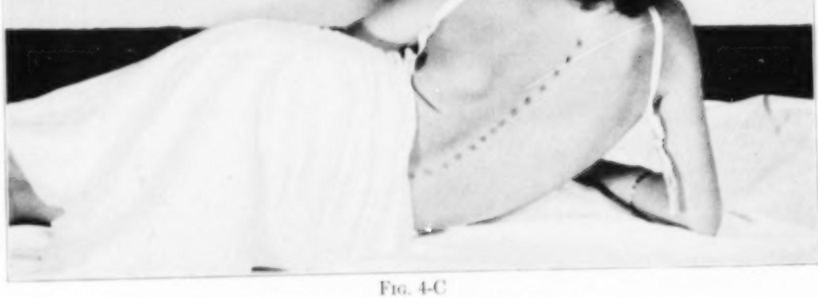

Fig. 4-C
Lateral recumbency on the right elbow.

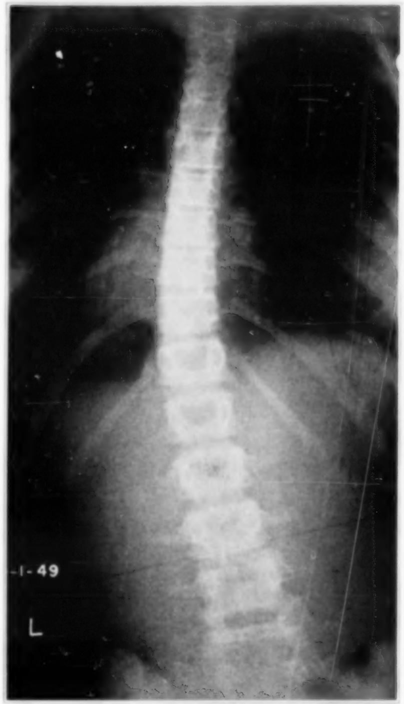

Fig. 5-A

Patient A. E. on April 1, 1949. Roentgenograms illustrate a left total curvature of 18 degrees.

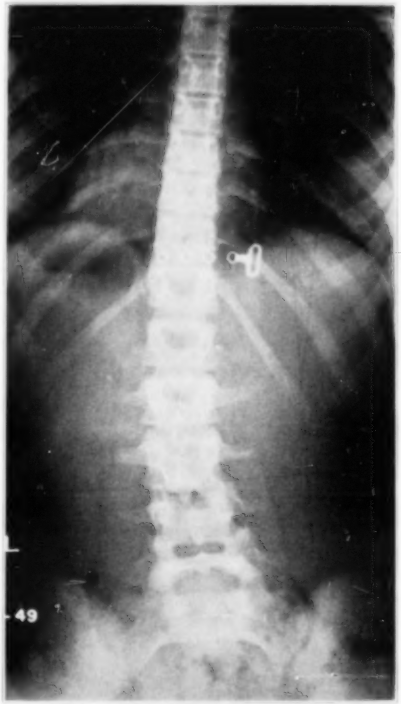

Fig. 5-B

Roentgenograms made October 4, 1949. The curvature was diminished to ten degrees.

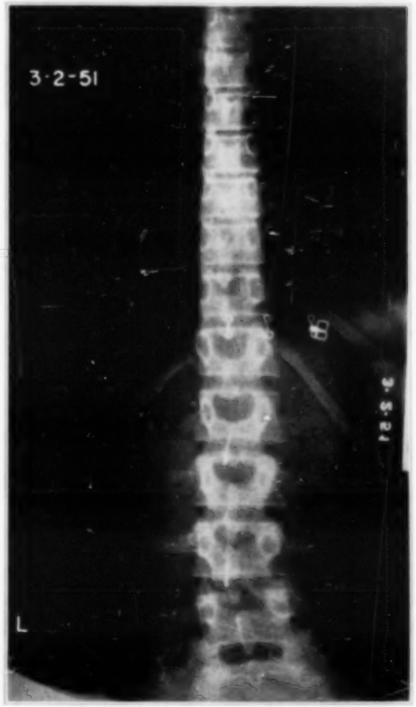

Fig. 5-C

Roentgenogram made March 2, 1951. The curvature has been corrected.

tissue contracture. Despite the fact that no such contractures can be found in idiopathic scoliosis, and despite the fact that division of the soft tissues in the concavity of the curve was found ineffectual long ago [3], the notion of a contractural etiology has been difficult to dispel, perhaps because a bowstring is easier to imagine than are the invisible staples of gravity. Nevertheless, all the available evidence points to the fact that, in idiopathic scoliosis, gravity, acting upon a spine made vulnerable by a functional curvature, is the only deforming force.

Removal of either of these two essential factors will prevent the development of structural scoliosis or, if it is already present, stop its progression. For example, the effect of gravity can be removed by recumbency. Thus, as already noted, structural changes do not develop in the horizontal spines of quadrupeds and progression of idiopathic scoliosis in children is halted by recumbency. While this is good evidence that the chief factor in idiopathic scoliosis is a gravitational one, prolonged recumbency is hardly an acceptable method of prophylaxis in man, who has so laboriously evolved the upright posture. A better method is to attack the other factor by correcting the functional curve before it becomes structural.

Fortunately for our purposes, the majority of functional curves are of a type which lends itself to a relatively simple method of correction. S-shaped functional curves, not suitable for correction by this method, are uncommon; most functional curves are of the C-shaped or "total" variety in which the entire spine is taken up by one gradual curve [7]. Such a C-shaped curve may be corrected by using the pelvis as a convenient lever or handle rigidly attached to the spine. Figure 4-A is a roentgenogram of such a left total curve taken in the erect position in a girl fourteen years old. Figure 4-B shows the same patient, same day, standing with a lift of one and a half inches under the left heel. This raises the left side of the pelvis sufficiently to straighten out the curve. With the functional curve corrected, the spine is no longer vulnerable to gravity-induced structural changes.

Less than half of a child's waking day is spent standing. The tendency to curvature must be combated in the sitting position as well. The pelvic tilt in sitting may be maintained by placing a book or similar object, such as a cushion, under the buttock on the same side as the shoe lift. A book is most convenient, especially in school.

Finally the curvature can be reversed in recumbency by propping the torso up on the elbow of the opposite side (concave side down; Figure 4-C). A hammock may be used in place of a bed, and the position shown may be quite comfortably maintained for two or three hours while the patient is doing homework or watching television.

The result of such a regimen is that the original functional scoliosis is eliminated, and the spine is maintained in a corrected position for the child's entire waking day. As will be seen below, when the spine has been thus corrected, and overcorrected (as in lateral recumbency), not only is structural change prevented, but the functional curve itself may in time disappear. Two illustrative cases are reported.

CASE REPORTS

CASE 1. A. E. was a ten-year-old girl when first seen on October 11, 1946. Her previous medical history was irrelevant. She had no history of poliomyelitis. The chief complaints were poor posture and awkward gait, which had been present since infancy.

Findings at general physical examination were within normal limits. Orthopaedic examination revealed a long, slender physical type, with mild relaxation of the ligamentous structures. She had bilaterally weak feet, mild recurvatum at elbows and knees, external torsion rotation of the tibiae, and internal torsion of the femora. Her posture was marked by an exaggeration of the lumbar lordosis and a mild dorsum rotundum. There was no lateral curvature. Both lower extremities were equal in length. She was instructed in symmetrical postural exercises, which she thenceforth did at home, and given shoe corrections for her weak feet.

She was seen three times in 1947 and it was noted that her weak feet and tibial torsion had improved. Her posture was unchanged, although she was doing her exercises faithfully at home. In March 1948 no

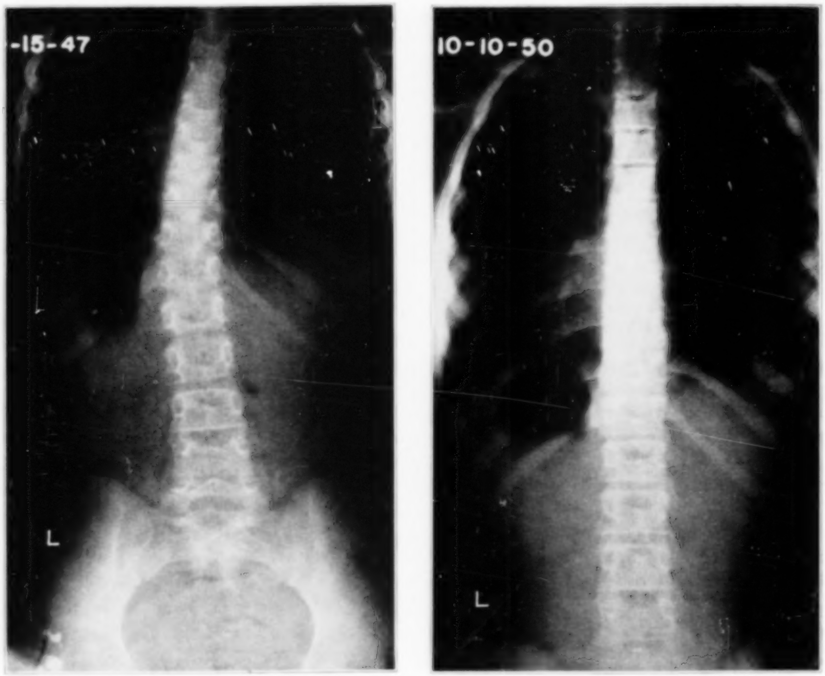

FIG. 6-A FIG. 6-B

Fig. 6-A: Patient V. B. on April 15, 1947. There was a curvature of thirteen degrees.
Fig. 6-B: Roentgenogram made October 10, 1950. The curvature has been corrected.

scoliosis was present, but the posture was unimproved. Her exercises were reviewed with the physical therapist; she did them well.

On June 3, 1948, it was noted for the first time that, when she relaxed in the standing position, a slight left total curve appeared. This was immediately obliterated when she actively straightened up. It was accompanied by a little prominence of the right hip as compared with the left. The left shoulder was a little higher than the right. Although it was noted that the curve was obliterated by a half-inch lift under the left heel, no lift was ordered at that time. Her symmetrical postural exercises were reviewed, and she continued them at home.

The patient was followed at intervals until April 1, 1949. Despite faithful performance of her exercises, checked by an intelligent mother, the curvature progressed until on April 1, 1949, it amounted to eighteen degrees (Fig. 5-A). On this date a lift of one and a half inches was placed under the left heel, and she was ordered to place a book of corresponding thickness under the left buttock at all times when sitting. She began to spend two hours a day lying on her right elbow. Her postural exercises were continued unchanged. At no time did she have any difference in the range of lateral excursion to either side, or any evidence of muscle weakness or contracture. Her height on April 1, 1949, was sixty-one inches.

On October 4, 1949, after six months on this regimen, the curvature had diminished to ten degrees (Fig. 5-B). It was checked at three-month intervals and improved constantly. The patient was seen last on March 2, 1951. At this time her curvature had been completely corrected clinically and roentgenographically (Fig. 5-C). Her height was sixty-two and one-half inches. The roentgenograms in this case and in the case which follows were all made with the patient erect, relaxed, and barefoot.

CASE 2. V. B., female, was ten and one-half years old when first seen on April 15, 1947, in the orthopaedic clinic at Bellevue Hospital. Roentgenograms made at another hospital six months earlier were reported to have shown a scoliosis. The patient had been hospitalized in 1938 with a pneumonia which was very extensive and which involved the entire left side of the chest. No empyema had developed. Her previous history was otherwise irrelevant. Examination on April 15, 1947, (by Dr. A. I. Blieden) revealed a small thin child with a moderate left thoracolumbar curvature with moderate rotation. The trunk was shifted to the left on the pelvis. It was noted that "There is some rigidity in the dorsolumbar curve, but correction can be obtained and can be held by the patient". Shoulders, scapulae, and pelvis were level. Both lower extremities measured twenty-seven and one-quarter inches. Roentgenograms made on this date revealed a left total or C-shaped curvature amounting to 13 degrees, with the apex at the thoracolumbar junction (Fig. 6-A). She was started on gymnastic exercises at this time. Re-examination in August 1947 and in May 1948 revealed no improvement. The scoliosis persisted and it was noted that there was some flattening of the thoracolumbar segment on forward flexion. Another orthopaedist (Dr. A. J. Pisani) believed that there was "rigidity of the back and soft-tissue contracture" (August 21, 1947).

On May 6, 1948 she was seen by the author for the first time; a lift of one and a half inches was placed under the left heel and under the left buttock when sitting from this time on. She began to spend two or three hours daily in lateral recumbency on her right elbow and continued her exercises. Improvement in the curvature was slow but steady. Final x-rays on October 10, 1950, showed complete correction of the curvature (Fig. 6-B). The flattening of the lumbodorsal region on forward flexion had practically disappeared. (This case had some of the features of a structural scoliosis, although there was no definite wedging of the vertebral bodies, and hence resembled the so-called "transitional scoliosis" of Lovett).

It is not known whether bowstring contracture or muscle asymmetry initiated the curve in either of these two cases. The contracture noted by Dr. Pisani may well have been accommodative. Certainly whatever contracture existed did not seem to interfere in any way with the correction of these curves. It is the author's opinion that, in idiopathic scoliosis, contractures which are too insignificant to be apparent are too insignificant to be of any importance in treatment.

It is interesting to note that the principles upon which this method of correction of curvature is based were in use as far back as 1743, when the English edition of Nicolas Andry's famous textbook advised "if a Child inclines his Shoulder too much to the right Side, make him support himself upon the left Foot" and ". . . if one Shoulder is too thick, he should always lie upon the opposite Side". Though these principles are not new, they have received remarkably little attention in the literature as compared with gymnastics and braces. When used, they have usually been applied half-heartedly, in small doses of one-half or three-quarters of an inch, mainly as an adjuvant to other methods and for purposes of cosmetic improvement. Such inadequate lifts, which are not sufficient to straighten the spine as checked by roentgenogram, may only delay or slow the progression of curvature rather than arrest it, since they do not completely equalize gravitational stress. The difference may or may not be made up by the daily period of recumbency, but it is better to use adequate lifts in the first place. These should be as high as can be tolerated, usually one and a quarter to two inches more than the opposite side, depending on the size of the child, and their effect on the curve should be checked by roentgenogram. The corrections are well tolerated because the corrective pressure is applied through structures adapted to weight-bearing and pressure (foot, lower limb, pelvis, and spine), rather than through the thoracic cage.

COMMENT

It is apparent from the foregoing that, if all functional curves were recognized and corrected, most structural curves could be prevented. The problem has been to recognize and correct the functional curves. These are commonly overlooked, especially when mild, or neglected when recognized. Even when they are actively treated, the usual methods of postural exercises and braces are often unsuccessful, partly because of the patient's lack of cooperation, partly because of defects inherent in the method. Postural exercises, though useful, are effective only at the actual moment they are being done; the gravitational pressure is symmetrical only while the spine is actually straight. Fifteen minutes of daily physical therapy are easily outweighed by fifteen hours of slumping. Braces, if effective, are conspicuous and often uncomfortable because of pressure on the rib cage; they usually meet with marked resistance on the part of the patient. In fact, the physician is often reluctant to prescribe a brace, knowing that the patient will not wear it for what seems to be a trifling postural defect. Later, when structural changes become obvious, the patient is willing, but the time for effectiveness is past.

On the other hand, shoe and buttock corrections are comfortable, inconspicuous, and readily accepted by the patient. Lateral recumbency is not particularly difficult to enforce if it is the position used for homework and television hours; perhaps it may not be essential if the curve is well corrected by the pelvic tilt. It is hoped that the ease and simplicity of this method will stimulate early recognition and adequate treatment of functional curvatures. To be sure, the majority of these curvatures will not progress even when ignored — witness the infrequency of structural scoliosis following inequality in length of limbs — but until we can distinguish those which are potentially dangerous all must be treated and, if possible, corrected.

All of the foregoing deals with the correction of functional curvatures. Equally interesting is the possibility that similar methods may prove useful in correcting the actual wedged vertebrae of structural scoliosis by what may be called "piezo-equalization" of vertebral growth. Selected cases of this sort are now under treatment and will be reported in a later article.

SUMMARY AND CONCLUSIONS

1. Gravity acting upon a growing spine which is not straight can produce structural scoliosis due to pressure-arrest of epiphyseal growth.
2. The early recognition and treatment of functional curvatures is therefore of primary importance in the prophylaxis of structural scoliosis.
3. Certain common types of functional curvatures can be corrected by tilting the pelvis by shoe and buttock lifts, thus preventing progression into structural scoliosis.

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FASCIAL ARTHROPLASTY OF THE KNEE

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Interest in arthroplasty of the knee has been heightened by the recent favorable report on nylon as an interposed membrane.[4] It is felt that a review of a number of cases of fascial arthroplasty of the knee might be of interest to afford a basis for comparison.

This paper is based on an analysis of arthroplasties of the knee which have been performed on the Orthopaedic Service of the State University of Iowa Hospitals during the thirty-year period from 1917 to 1947. For this study, thirty-seven arthroplasties of the knee were reviewed. The period of postoperative follow-up ranged from three to fifteen years. No operative deaths occurred in the series.

The operations were performed by several surgeons, many of whom were residents,—a factor which must be considered in the evaluation of results, for experience is no doubt of considerable importance in so complex a procedure.

TECHNIQUE OF OPERATION

Two types of surgical approach have been employed in most of the cases. The U-shaped incision described by Putti was used in many of the earlier cases, but it was later abandoned in favor of the medial parapatellar approach, which is not as apt to interfere with the nutrition of the skin flaps. In the first arthroplasties done, reconstruction of the joint surfaces along normal anatomical lines, as advocated by Putti, was the procedure of choice. For most of the patients, however, the Campbell method of modeling a large, convex femoral condyle, fitting into a concavity fashioned from the upper tibial articular wedge, was used[2,3,7]. In two, Albee's procedure of forming a wedge of the femoral condyles in the frontal plane was used[1] and the reconstructed surfaces of femur, tibia, and patella were covered by fascia lata. In eight patients in whom the knee had been ankylosed in extension, quadriceps-tendon-lengthening was done.

In one third of the cases, attempts were made to overcome existing flexion contractures prior to arthroplasty. These procedures included: manipulation, traction, and turnbuckle casts. Hamstring-lengthening, with and without posterior capsulotomy or supracondylar osteotomy, was done in a few instances as a preliminary procedure.

ANALYSIS OF CASES

For the purposes of statistical analysis, standards of joint motion, pain, and stability were established to evaluate the results of the operations. A result was considered good if the reconstructed knee showed 45 degrees or more of painless active motion and if the stability of the joint was such that no brace or other support was necessary for ambulation. The result was classed as fair if there was active painless motion of 35 to 45 degrees in a functional range with good joint stability, if there was a greater range of motion but with pain on prolonged walking or standing, or if there was instability necessitating the use of a brace. The result was considered poor if there was less than 25 degrees of active motion, or if pain or instability was incapacitating.

Because it was felt that the success or failure of arthroplasty of the knee was related to the etiology of the ankylosis, the cases have been divided into three groups: In the first group are the patients with polyarticular arthritis of the atrophic type; in the second group are included patients in whom the ankylosis resulted from an inflammatory process limited to one joint; and in the third are the small number of patients in whom ankylosis followed trauma without infection.

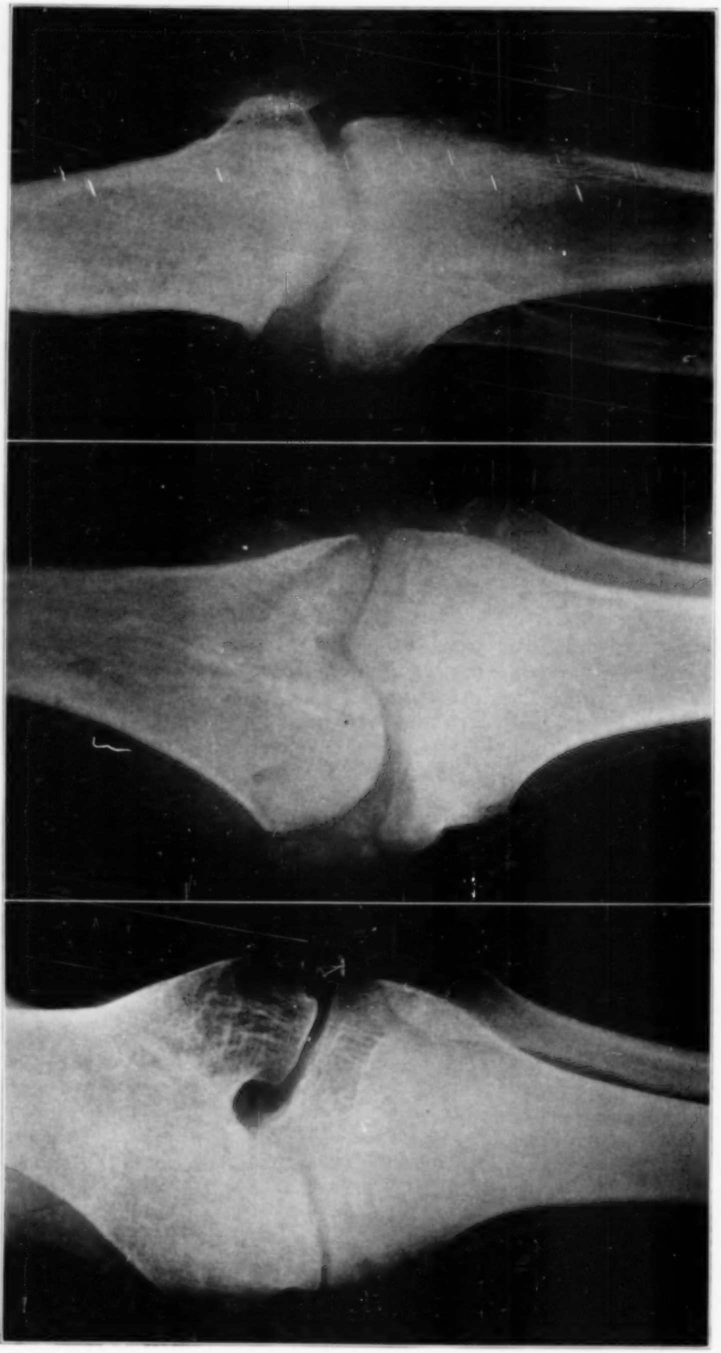

FIG. 1-A

FIG. 1-B

FIG. 1-C

Fig. 1-A: Ankylosis in a male, seventeen years old, following osteomyelitis of the distal end of the femur, with joint involvement, eight years before.

Figs. 1-B and 1-C: Anteroposterior and lateral roentgenograms taken two and one-half years following arthroplasty. The range of motion was 40 degrees, limited beyond that point by adhesion of soft-tissue structures to the distal portion of the femur.

Polyarticular Atrophic Arthritis

In view of the unsuccessful results experienced here and elsewhere in cases with ankylosis of many joints, arthroplasty was undertaken only after the patient had been acquainted with the probability of failure. Where possible, selection was based upon the favorable condition of bones and muscles, and upon age. Exceptions were made, however, for those in whom both hips and both knees were ankylosed. Because of the severe disability in these patients, an attempt at neo-arthrosis seemed warranted, although a completely successful outcome could hardly be hoped for.

A total of twenty arthroplasties of the knee were performed on patients with polyarticular atrophic arthritis. In this group there were six successful results (30 per cent.); four patients showed definite improvement (20 per cent.), while ten were classed as failures (50 per cent.). The poor results were chiefly due to lack of sufficient motion. Lateral instability was not an important factor except in one patient.

Monarticular Inflammatory Arthritis

There were fourteen arthroplasties in this group. The results for the group were: five good results (36 per cent.), four fair results (28 per cent.), and five failures (36 per cent.). The etiology of the ankyloses in this group of patients ranged from blood-borne infections, including gonococcal and other pyogenic infectious processes, to local infections with secondary involvement of the knee joint by extension. In general, there was no correlation between the specific etiology of the ankylosis and the result of the arthroplasty. However, those patients in whom there had been extensive fibrosis of the periarticular soft tissues did not respond to the operation as favorably as those in whom the soft tissues were relatively normal.

Non-Infectious Post-Traumatic Ankylosis

Ankylosis due to trauma without infection has been a rare occurrence. In this series there were only two patients with involvement of this type who came to arthroplasty. In both instances, arthroplasty failed because of postoperative infection. An attempted re-arthroplasty in one of these was unsuccessful.

THE CAUSES OF FAILURE

The failures experienced in this series will be discussed under three main headings: (1) the selection of cases, (2) the operative technique, and (3) the postoperative complications. It should be pointed out that, in a number of patients, combinations of these factors, no doubt, were responsible for the poor outcome.

1. The Selection of Cases

Early in the experience of this Clinic with arthroplasty, it became apparent that patients with ankylosis of the joints due to atrophic arthritis were poor candidates for the operation. Long recumbency and, in some cases, fusion of the hip and the knee on the same side resulted in advanced atrophy of the muscles. Even in those in whom a good range of passive motion could be obtained with arthroplasty, little active motion was regained. Occasionally, in patients with ankylosis of both hips and knees, arthroplasty of the knee, in combination with hip surgery, was justified if only because it allowed these persons to sit and lie more comfortably. However, the strong urge to do something for these hopelessly disabled patients has led to surgery from which a functioning joint can rarely be expected.

An additional caution in cases of long chronicity is the difficulty of establishing the time at which the arthritic process became quiescent. Exacerbation of the arthritis with subsequent loss of motion following arthroplasty has occurred in four patients in this series. In each instance the disease was considered to have been inactive, by clinical and

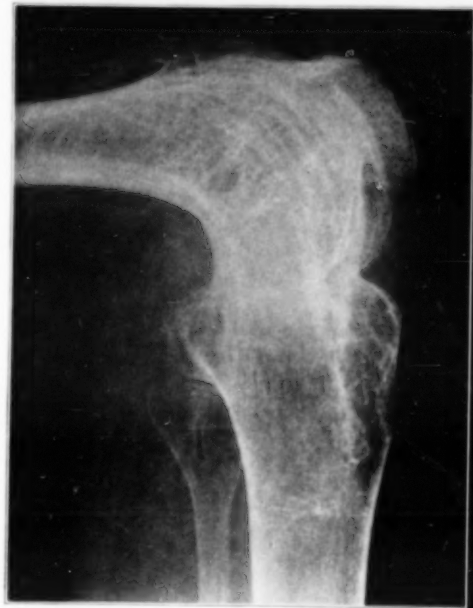

FIG. 2-A

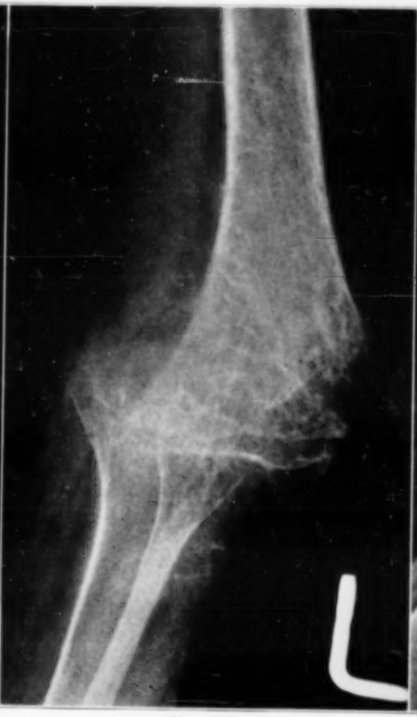

FIG. 2-B

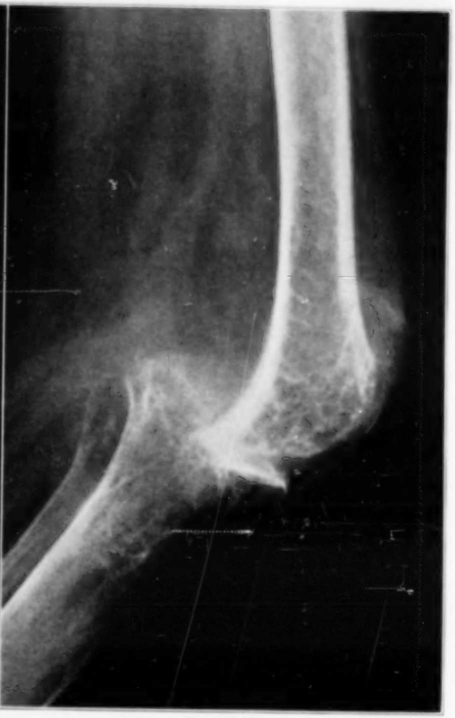

FIG. 2-C

Fig. 2-A: Bony ankylosis following atrophic arthritis in a woman, twenty-seven years old. The knee is fixed in flexion of 90 degrees and the bone is osteoporotic.

Figs. 2-B and 2-C: Oblique and lateral roentgenograms taken eleven months after arthroplasty. Because of the severe degree of bone atrophy, modeling of bone ends was difficult.

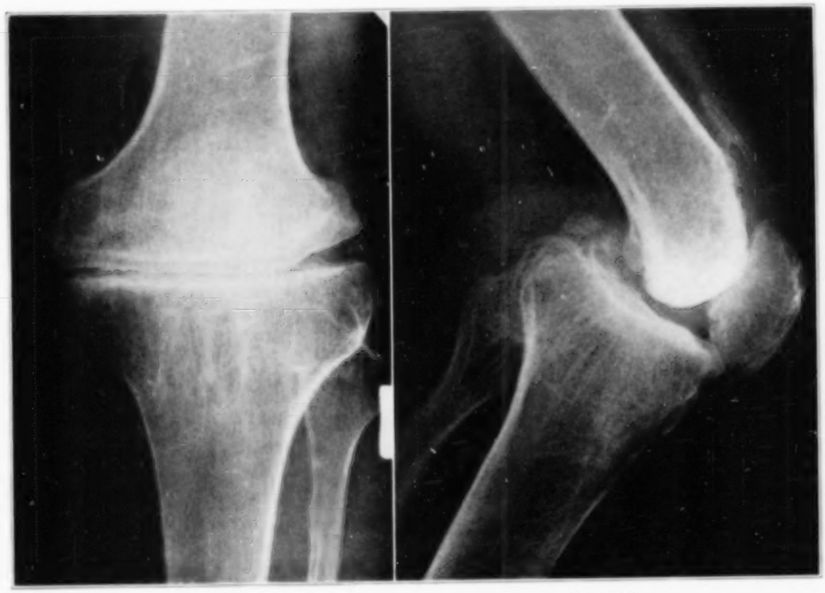

FIG. 3-A

FIG. 3-B

Anteroposterior and lateral roentgenograms taken fourteen and one-half years following an arthroplasty performed for an ankylosis due to atrophic arthritis. Shows adequate resection of articular surfaces and good modeling of bone ends. Patient has 80 degrees of active motion with a stable, painless knee, and works as a laborer without difficulty.

laboratory examinations, for at least a year prior to surgery. Information about fleeting pain is seldom volunteered by the patient, and only detailed questioning may prevent operation upon a joint which is still the seat of latent activity.

Particularly poor prospects for arthroplasty were found to be those patients in whom ankylosis had resulted from osteomyelitis of the bony structures around the knee. In these cases, the bone had usually become densely sclerotic, making it unsuitable for reconstruction; and there was frequently severe damage to the surrounding soft tissues with fibrosis and loss of the functional capacity of muscles and ligaments (Figs. 1-A, 1-B, and 1-C). All of these structures may be so attached to diseased bone that a harmful amount of stripping may be necessary before the bone ends can be exposed. Walled-off foci of infection may be opened, re-establishing the osteomyelitic process.

Patients with atrophic bone present difficulties in joint reconstruction (Figs. 2-A, 2-B, and 2-C). Not only is bone modeling troublesome, but collapse and resorption under subsequent weight-bearing has occurred. In one patient, resorption of the anterior surface of the tibia produced an anterior dislocation of the femur. Subchondral cysts have been encountered upon excising the old articular surfaces with impairment of the operative result. To some extent atrophy of the bone can be overcome by a preliminary period of weight-bearing, while sclerotic bone, because of its resistance to functional adaptation, has proved to be inferior material for arthroplasty. A careful study of the roentgenograms, especially for bone structure, is then of primary importance in the selection of cases.

Deformities of the knee were usually present in patients appearing for arthroplasty. These usually consisted of flexion contractures. Occasionally genu valgum or genu varum was present; more rarely, a mild or moderate degree of subluxation was seen. In patients in whom the deformity was mild, preliminary correction was not found to be necessary,

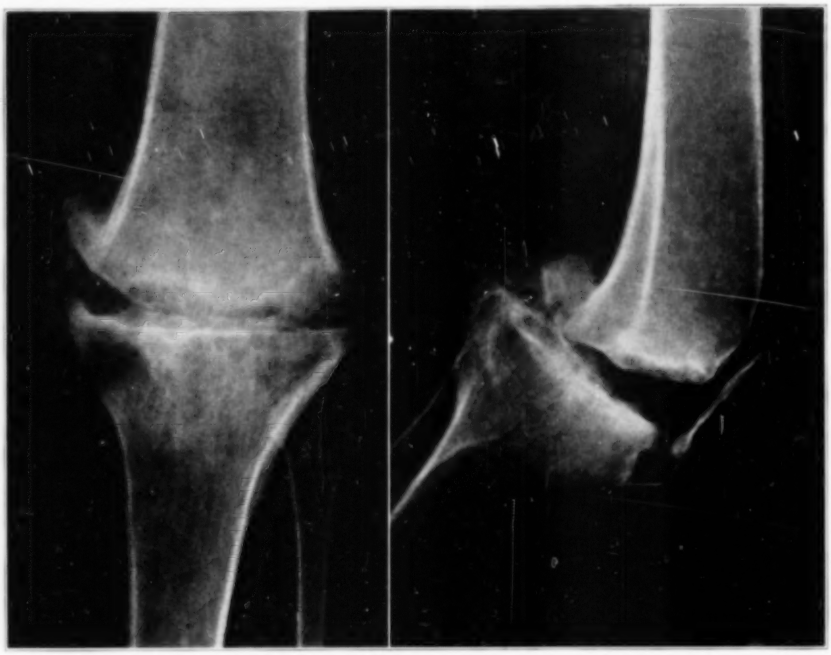

FIG. 4-A FIG. 4-B

Anteroposterior and lateral roentgenograms taken six years following an arthroplasty. Excessive bone formation at the lateral joint margins is evidence of the stripping of lateral ligamentous and capsular structures. Patient had flexion of 90 degrees but severe lateral instability.

as evidenced by a comparison of results in patients who had been subjected to preoperative correction with the results in those who had not. In all such patients, no obstacle to realignment of the joint was encountered once the ankylosis had been overcome. The reduction in hospital time and the avoidance of additional fibrosis in patients who had undergone surgical correction justified the elimination of these preliminary procedures except in instances of unusual deformity. It must be emphasized, however, that these patients, whether treated prior to the arthroplasty or not, do not show as favorable an end result as those in whom joints were fused in good position.

2. The Operative Technique

In four patients, the U-shaped Putti incision, curving distally to the patella, was used. In two of these, sloughing of the margins of the flap, with infection, was responsible for the poor results obtained. Consequently, the medial parapatellar incision with lateral displacement of the patella is now used.

Of prime importance has been the removal of sufficient bone to restore a satisfactory joint space (Figs. 3-A and 3-B). Although the removal of too much bone may result in an unstable joint, the error in the majority of cases lay in the incompleteness of joint resection. Even though only two of the poor results in this series could be definitely attributed to the insufficient removal of bone, many of the fair results would undoubtedly have had a good range of motion had more bone been removed at the time of operation.

Precaution must be taken to prevent valgus and varus deformities due to poor modeling of the femoral and tibial joint surfaces. Genu varum developed in one patient in this series because of poor modeling.

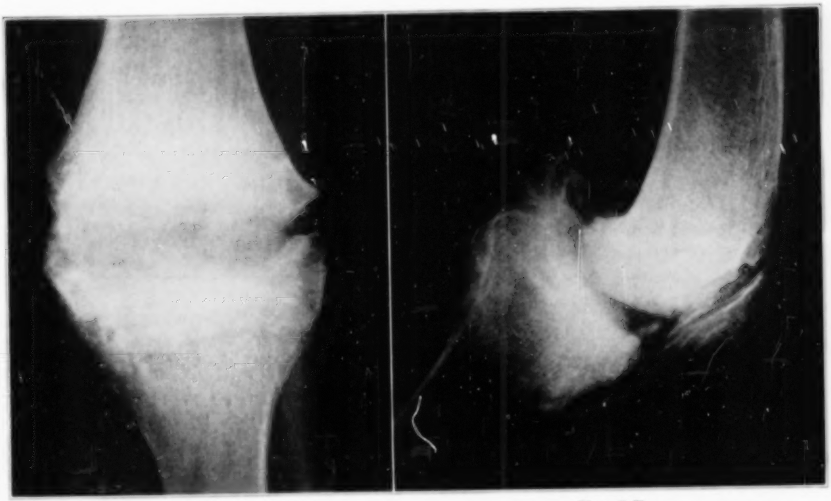

Fig. 5-A Fig. 5-B

Anteroposterior and lateral roentgenograms taken three years after arthroplasty performed at the age of sixteen years. In spite of the proliferation of bone surrounding the joint, patient had active motion of 90 degrees in a painless stable knee joint.

Extensive stripping of the lateral structures produced a loss of stability sufficiently great to interfere with the result of the arthroplasty in nine patients. In two, lateral instability was the chief cause of failure. Secondary reconstruction of the collateral ligaments was done, but the amount of improvement was slight. Careful preservation of these structures might have prevented this complication in some patients (Figs. 4-A and 4-B).

The results in two patients were complicated by an excessive formation of periosteal bone. The operative history in one of these gives the information that an unusual amount of stripping was necessary to secure good exposure. However, except in these two patients, the reaction to stripping has not been of major importance in relation to the end results. On occasion, an excellent range of motion has been obtained in spite of abundant formation of new bone as seen in the postoperative roentgenograms (Figs. 5-A and 5-B).

The inability to control hemorrhage from the denuded bone may play a role in some instances of failure. In one patient who came to re-arthroplasty, an old blood clot undergoing organization was found in the intra-articular scar tissue. This emphasizes the possibility that resorption may not always follow, but that organization of the encapsulated blood with resultant adhesions may occur. Moreover, the fascia lata was seen on several occasions to be lifted off the joint surfaces by hemorrhage from the underlying bone during the course of the operation. Release of this blood by puncturing the fascia was necessary. A third complication of hemorrhage is the possibility that the blood in the new joint space may serve as a favorable site for infection.

3. Postoperative Complications

Of all the postoperative complications, exacerbation of the original disease process following the operation has been the most important cause of failure. In four patients, the arthritis which had been quiescent for at least a year before surgery became reactivated, and loss of motion resulted. In another patient, a suppurative joint process was rekindled by the operation which resulted in subsequent re-ankylosis. While this complication may be preventable in some instances, it appears that in others it will occur in spite of the most careful preoperative clinical, roentgenographic, and laboratory examinations.

Wound infections in two patients were responsible for the failure of the arthroplasty. In two other patients infections occurred, but these were adequately drained, and the joint retained good motion. Prompt recognition and institution of treatment may prevent an unfavorable outcome in some patients in whom postoperative infections occur.

Severe pain, persisting after healing has taken place, has been infrequent. When pain of this nature has occurred, it has usually been in association with marked instability. Braces or other support gave relief to these patients. A mild degree of aching pain following prolonged walking or standing was somewhat more common, but it was by no means incapacitating. While the exact cause of the discomfort cannot always be determined, in part it must be attributed to the faulty mechanics of the reconstructed joint.

Another complication, although not directly due to the arthroplasty, was fracture of the femur. In two patients, this occurred several months after weight-bearing had been resumed, as a result of trauma sufficient to cause a fracture. These were not considered to be pathological fractures. In both instances some stiffening of the reconstructed joints followed immobilization for the fractures.

Limitation of motion in the first few months after surgery did not necessarily portend a poor final outcome. In many of the patients, it was noted that the full extent of motion to be gained did not appear for as long as two or three years after the operation. This was dramatically illustrated in one patient who had less than 20 degrees of motion in the reconstructed knee two months after the operation. He failed to return for an examination until three years later, at which time he had 90 degrees of active painless motion in the joint; and had been working as a laborer without difficulty.

MANIPULATIONS

For a period of time manipulations under general anaesthesia were frequently used after the operation, and it was hoped that by this means additional motion could be obtained in refractory cases. However, it soon became apparent that, while immediate improvement could be consistently gained, the additional motion was soon lost. Moreover, the manipulative procedure was not always without complication, which was not of a serious nature. We concluded that no real benefit can be expected from such treatment, and it has been superseded by less forceful therapy.

THE INTERPOSED TISSUE

In ten patients re-operation afforded an opportunity to view the new joint four months or more after the original arthroplasty. In none of the re-explorations could tissue identifiable as fascia lata be seen at the points of weight-bearing; but, in all, rims of fascia covering the joint surfaces were evident elsewhere. In six patients with limited motion, dense intra-articular adhesions existed between femur and tibia. In one of the cases with fair motion, a few adhesions were present, while in the three others the weight-bearing surfaces were covered by a layer of smooth fibrous tissue. Specimens removed were seen on microscopic examination to consist of dense fibrous tissue in which small islands of necrotic connective tissue, presumably fascia, were visible. It would seem, therefore, that Phemister and Miller's experimental findings are borne out by these clinical observations. Apparently the coverings of the new joint surfaces are derived from the exposed marrow spaces of the denuded bone and the interposed fascia plays a secondary role in the construction of the new joint coverings. The development of articular coverings in cases of pseudarthrosis following non-union of a fracture, in which no interposed fascia plays a part, supports this viewpoint.

SUMMARY

In an analysis of thirty-seven arthroplasties of the knee, there were eleven good results (30 per cent.), eight fair results (22 per cent.), and eighteen failures (48 per cent.).

Particularly poor candidates for arthroplasty have been those patients with polyarticular ankylosis resulting from atrophic arthritis. Ankylosis due to extension of an osteomyelitic process about the knee joint gave similarly poor results.

The most favorable results from the operation were obtained in cases where the knee joint was involved secondarily by a blood-borne infection.

Concerning the operative technique, the medial parapatellar incision combined with Campbell's method of joint reconstruction was adopted as the procedure of choice. The importance of resecting adequate bone for maintaining the new joint space, accurate modeling of the opposing articular surfaces for joint alignment, and retaining the lateral capsular and ligamentous structures for stability cannot be emphasized too highly.

The postoperative complications which most frequently led to failure were the reactivation of the arthritic or infectious process and infection introduced by the operative procedure.

From the analysis of the above cases, it is apparent that a new joint of sufficient mobility and stability, with freedom from pain, is not a constant result. However, the unusual benefits derived from a successfully mobilized knee make the operation of arthroplasty of great value in the carefully selected cases of ankylosis. The operation should be advised only after the patient has been made aware of its limitations.

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DISCUSSION

Local Stimulation of Growth of Long Bones

(Continued from page 24)

interference on the normal legs. It is well known that there have been some unhappy results from epiphyseal arrest. Furthermore, limb shortening or inhibition of growth of the extremity to equalize length often alters the individual's physique.

It is hoped that this paper will stimulate further interest in the study of bone growth in children, a field which offers great opportunity for developments. For example, no one has yet worked out the percentage of cases, at various ages, in which overgrowth of the femur remains as a result of fracture of this bone. Similarly, no one has yet made a complete study on osteomyelitis of the long bones to determine in what percentage of cases overgrowth persists or to determine if there is a premature closure of the epiphysis after temporary stimulation of growth as the result of infection.

ARTHRODESIS OF THE WRIST

PRELIMINARY REPORT OF A NEW METHOD *

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Arthrodesis of the wrist is a commonly applied measure in the orthopaedic armamentarium. Methods already reported in the literature are largely variations of the graft-type of procedures described by Abbott, Brittain, Gill [3], and Smith-Petersen. Although satisfactory fusion can generally be obtained by these methods, several difficulties are presented:

The fate of a free graft is by no means certain, and fracture of the graft and non-union are not uncommon;

Fracture of the radius at the proximal end of the graft bed has occurred;

The period of immobilization varies greatly, and is rarely under three months;

The final position is maintained solely by plaster immobilization, and is subject to deterioration if the cast becomes weak or is changed.

To avoid these difficulties, a method has been devised, consisting of resection of the proximal row of carpal bones with fixation of the capitate to the radius by means of a screw. In this way, viable cancellous bones, with an intact blood supply, are apposed to one another, and the internal fixation provides a positive means of maintaining position. Changing the cast provides no problem whatever. Cancellous grafts are used to reinforce the fusion, but healing is not dependent upon any grafted bone. These factors have improved the rapidity and the certainty of healing, both of which are vital in allowing the patient to return to work early.

PROCEDURE

A curved, longitudinal incision is made over the dorsal aspect of the wrist, convex radially. The extensor tendons are retracted, and the dorsal aspect of the wrist joint is exposed. The capsule is incised, and the navicular, lunate, and triangular are completely removed. Next, the articular surfaces of the radius, capitate, and hamate are removed with a chisel and gouge, until a surface of cancellous bone can be seen. A small, shallow depression is now gouged into the distal surface of the radius to accommodate the head of the capitate. The radial side of the incision is retracted, and the lateral aspect of the radial styloid is exposed 1.5 centimeters from its tip. A drill is run through the styloid into the depression made for the head of the capitate, followed by the insertion of a steel or Vitallium screw, one and one-quarter to one and one-half inches long. When the tip of the screw appears on the bottom of the depression in the end of the radius, the head of the capitate is forced into the depression. The screw can then be driven into the capitate without prior drilling of the bone. When this has been done, a firm fixation in proper position should have been accomplished. Chips of cancellous bone, taken from the removed proximal row, are now placed about the fusion site to round out the bony mass and to reinforce the fusion. Care should be taken not to extend the bony mass on to the dorsum, where it might interfere with the function of the extensor tendons. After routine closure, a long plaster cast is applied, which should extend from the axilla to the distal palmar crease. Care must be taken to leave the fingers and thumb free to function. The cast is split immediately to allow for swelling, and after ten days it is changed and the sutures are removed. If postoperative pain and swelling are troublesome, repeated stellate blocks are frequently useful. Immobilization is maintained for eight weeks following the operation, during which time active use of the fingers and the thumb is constantly encouraged. Four weeks after surgery, the long cast is cut down to a forearm cast, and active elbow motion is permitted. Recovery of function following removal of the cast is usually prompt with the assistance of a little physical therapy.

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* Sponsored by the Veterans Administration and published with the approval of the Chief Medical Director. The statements and conclusions published by the authors are a result of their own study and do not necessarily reflect the opinion or policy of the Veterans Administration.

Certain aspects of the technique are worthy of special mention: The screw should not be placed too far on the palmar side but must be sufficiently angulated dorsally to obtain a good bite in the capitate. While the screw should be long enough to hold firmly in the capitate, it must not cross the carpometacarpal joint. In some cases, particularly after previous operations, it may be difficult to delineate the bone arrangement without undue dissection. In these cases, the removal of a thin layer of bone and periosteum from the dorsal aspect of the radius and the carpal bones, in one piece, with a broad, thin osteotome is advised. Following this, the various carpal bones are easily identified. The thin layer of bone and periosteum may be replaced at the end of the operation.

Position of the Wrist for Fusion

The optimum position of the wrist for arthrodesis is generally given as from 20 to 30 degrees of dorsal angulation, or such that the opposed thumb is in line with the forearm. To this about 20 degrees of deviation of the wrist toward the ulnar side is added. This combination approximates the normal clenched fist position in which the grip is strongest. Unless a definite deviation of the hand toward the ulnar side is given, the use of the numerous tools and instruments which must be held in the hand and pointed away from the body—such as hammers, screw drivers, and fishing poles—is greatly interfered with.

The Distal Radio-Ulnar Joint

Where there is sufficient derangement of the wrist from injury to warrant an arthrodesis, it is not uncommon to find a derangement of the distal radio-ulnar joint as well. This is particularly true in fractures of the lower end of the radius, but has also been seen in old fractures of the navicular. Unless this condition is recognized, an otherwise successful fusion of the wrist may be considered a failure, since the patient will continue to have pain and weakness.

The diagnosis can generally be made by careful reading of the roentgenograms. The pain from this area is generally greater along the ulnar side of the wrist and forearm, and there is tenderness over the distal radio-ulnar joint. There may also be pain on motion and limitation of pronation and supination, and particularly pain on resisted supination. If doubt exists, the joint can easily be infiltrated with 1 per cent. solution of procaine from its dorsal aspect with the forearm in pronation. In this way, pain which has its origin in the joint may be relieved and recognized. In such instances, resection of the distal portion of the ulna is performed. The type of incision is altered in such a way as to be convex to the ulnar side in order to facilitate the exposure of the ulna. The screw is inserted through a separate stab incision over the radial styloid. Only enough of the ulna is removed to excise the joint, for excessive removal leads to instability of the ulna. The authors have found that the insertion of a small wad of oxidized cellulose over the raw end of the ulna effectively inhibits postoperative proliferation of bone and spur formation.

RESULTS

The operation has been performed twelve times on eleven patients, all of whom had traumatic arthritis of the wrist. In no instance has any complication arisen as a result

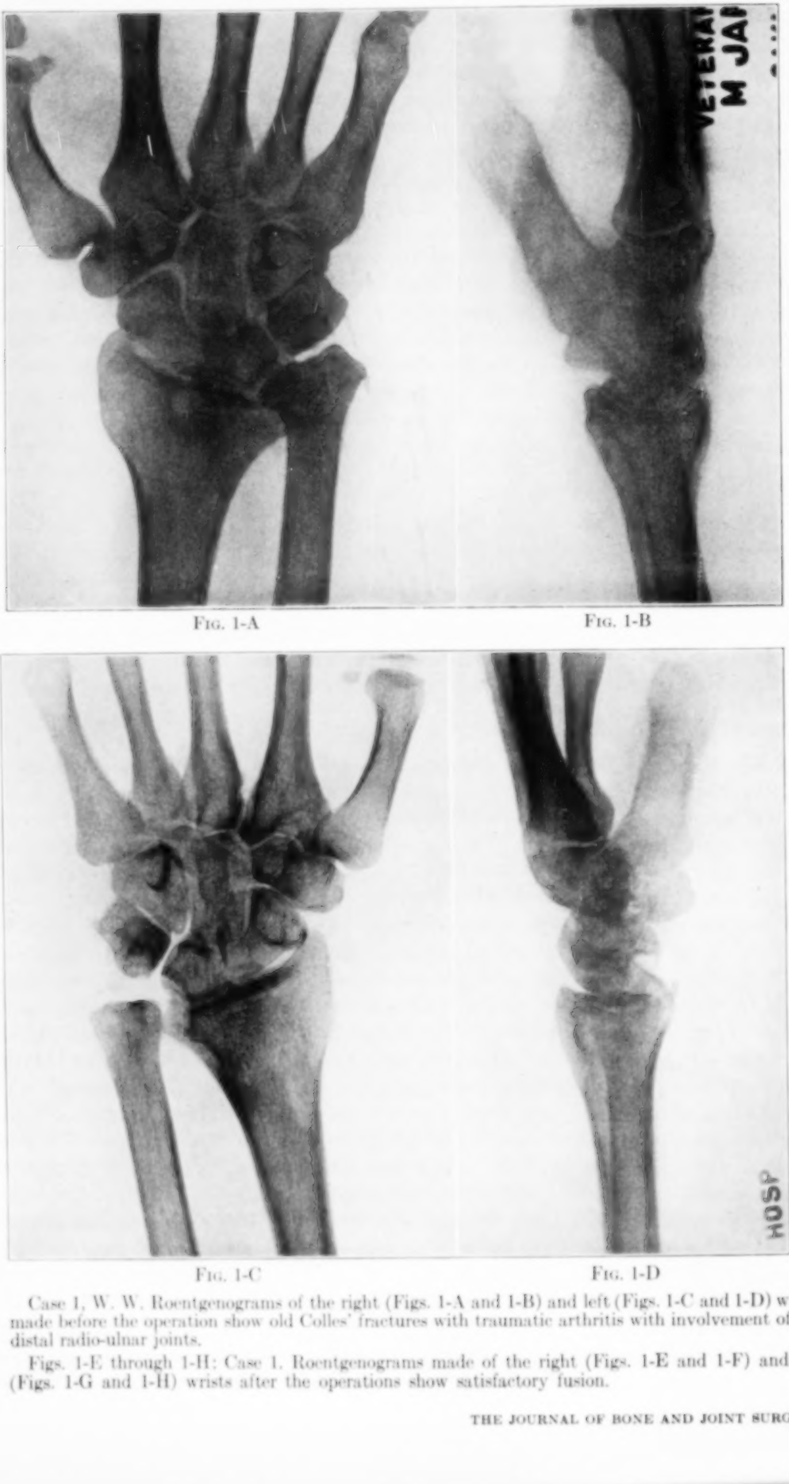

Fig. 1-A

Fig. 1-B

Fig. 1-C

Fig. 1-D

Case 1, W. W. Roentgenograms of the right (Figs. 1-A and 1-B) and left (Figs. 1-C and 1-D) wrists made before the operation show old Colles' fractures with traumatic arthritis with involvement of the distal radio-ulnar joints.

Figs. 1-E through 1-H: Case 1. Roentgenograms made of the right (Figs. 1-E and 1-F) and left (Figs. 1-G and 1-H) wrists after the operations show satisfactory fusion.

of the operation, and all wounds have healed by primary union. There has been no case of infection. No wrist has required immobilization for more than the appointed eight weeks, at which time solid union of the bone, both clinically and as shown by roentgenograms, has been found in each wrist. In no case has there been any evidence of reaction about the screw, and no screws have required removal; nor has there been any evidence of any change in position during the period of immobilization, or at the time of a change of cast. There has been no instance of any interference in any way with finger function. Within two weeks of the removal of the cast, all patients have been able to return to work. In this regard, however, a certain caution is warranted. It has been stated that arthrodesis of the wrist produces little if any disability; in general this has been found to be so. Persons engaged in grossly laborious occupations—such as farmers, stevedores, pick-and-shovel wielders and the like—do very well with a stable, painless wrist; in the same manner persons who work with their fingers, as in writing, find the stiffness of the wrist no encumbrance. However, those who use small hand tools, such as a screw driver, hammer, and pliers, have found that the loss of wrist motion greatly impairs their skill with these tools. This is a definite occupational handicap. Nevertheless, the freedom from pain and the improved grip are greatly appreciated.

The following cases are described in detail to illustrate the value of the procedure and the problems which may arise.

CASE REPORTS

CASE 1. W. W., a farmer, sixty years old, incurred bilateral Colles' fracture while in military service in World War I. He had been having progressive pain and stiffness of both wrists for the past five years. Examination revealed tenderness and marked limitation of motion in both wrists, with pain on pronation and

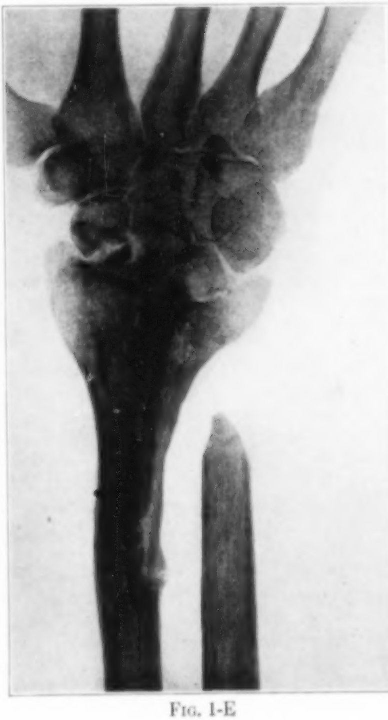

FIG. 1-E

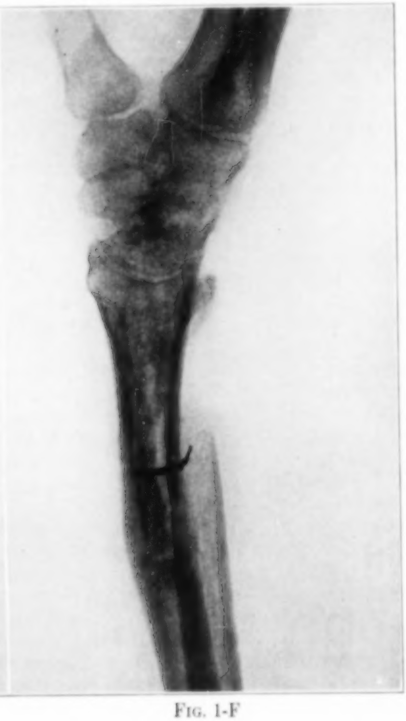

FIG. 1-F

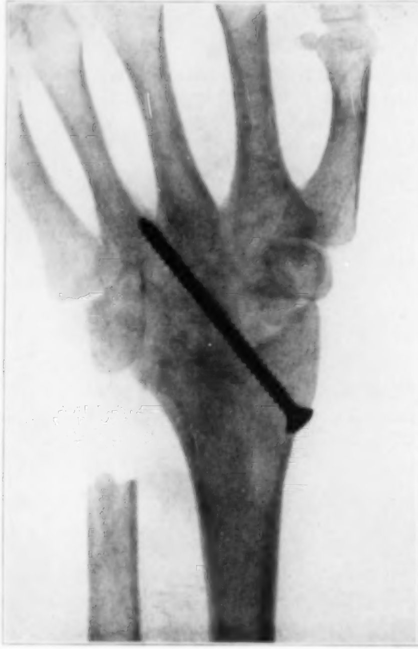

FIG. 1-G

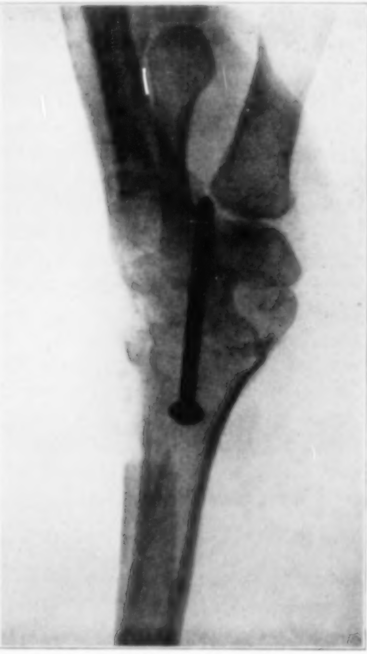

FIG. 1-H

supination; roentgenograms revealed traumatic arthritis of both wrists and of both distal radio-ulnar joints (Figs. 1-A to 1-D). Wrist fusion and resection of the distal aspect of the ulna on both wrists was indicated. The right wrist was operated upon first, on February 17, 1950, and a sliding graft, obtained from the dorsal surface of the radius, was used. The distal four centimeters of the ulna was resected. (This was more than was necessary and probably too much.) The postoperative course was uneventful. On March 16, 1950, the left wrist was operated upon. By May 12, 1950, solid union, both clinically and as shown by roentgenograms, was noted in the left wrist. Within two weeks, the patient had a full range of motion, with much better strength than before the operation, both in the fingers and in pronation and supination; there was no pain in the wrist. The right wrist, however, had to be immobilized for an additional four weeks after mobilization of the left wrist before healing was considered solid enough to allow active use of the hand. The result was clinically as satisfactory as that in the left wrist, but the right wrist required eight weeks longer in a cast. There was some question at that time as to the solidity of the fusion and the presence of motion (Figs. 1-E and 1-F). The patient, however, was unable to notice any difference between the two wrists as far as pain or finger strength was concerned. He stated that he felt quite able to go back to farming.

CASE 2. C. D., a man thirty-five years old, first injured his right wrist in 1942. He had received no treatment for two years, after which roentgenograms were made and a cast was applied for six weeks. He was later operated upon and some of the bones were removed from his wrist. There was considerable pain, tenderness, and limitation of motion. Roentgenograms revealed not only the absence of the lunate and part of the navicular but also considerable arthritic degeneration (Figs. 2-A and 2-B). Arthrodesis was done on March 9, 1950, but the position of the wrist after the operation was not entirely satisfactory. By May 5, 1950, there was solid bony union (Figs. 2-C and 2-D). Rehabilitation was begun, but the patient continued to complain of pain. A review of the situation revealed that the arthritis of the distal radio-ulnar joint had been overlooked and that resection of the ulna was indicated. It was felt that as long as another operation was to be performed, the position of the wrist could be improved at the same time. On July 11, 1950, the distal end of the ulna was excised and the fusion site was opened. The screw was then removed, and the ankylosis was broken up. With the wrist in more dorsiflexion, the screw was replaced. Once again solid union was noted in eight weeks and rehabilitation was begun. There was some difficulty with residual pain over the ulnar aspect of the wrist and forearm, but this gradually decreased under treatment. There was, however, no difficulty from the fusion, and the function of the fingers was completely normal (Figs. 2-D and 2-E).

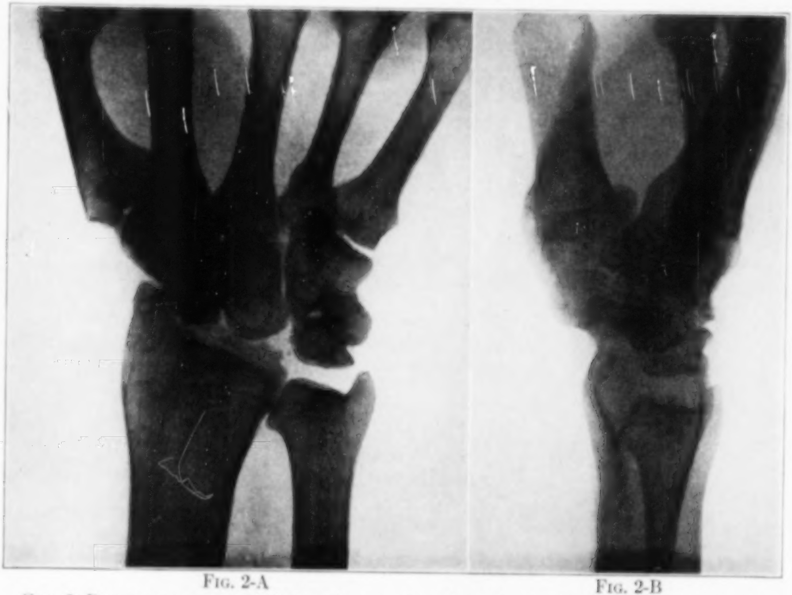

FIG. 2-A FIG. 2-B

Case 2. Roentgenograms made before the operation show the previous resection of the lunate and part of the navicular. There is also shown the presence of traumatic arthritis involving not only the carpal bones but also the radio-ulnar joint.

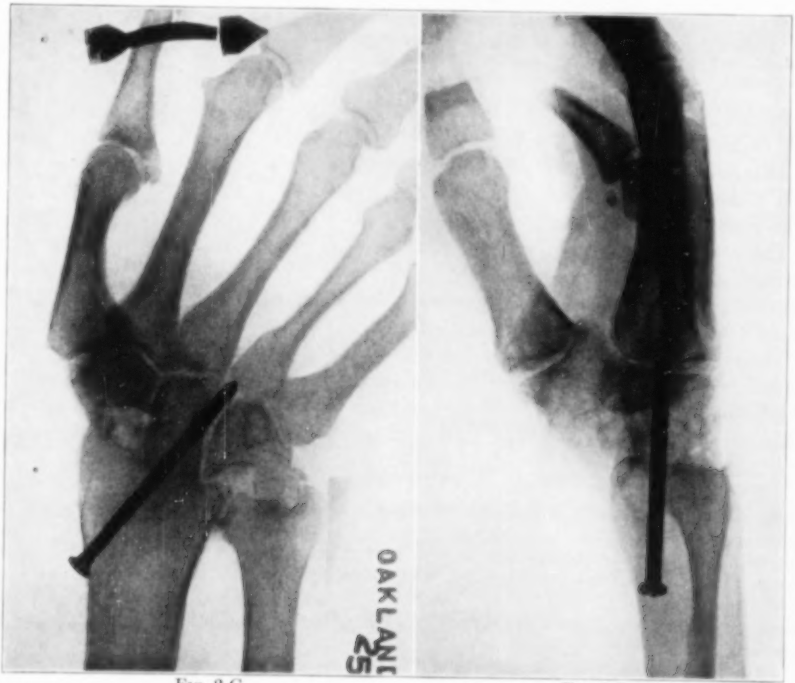

FIG. 2-C FIG. 2-D

Case 2. Roentgenograms made after the first operation show inadequate dorsiflexion of the wrist.

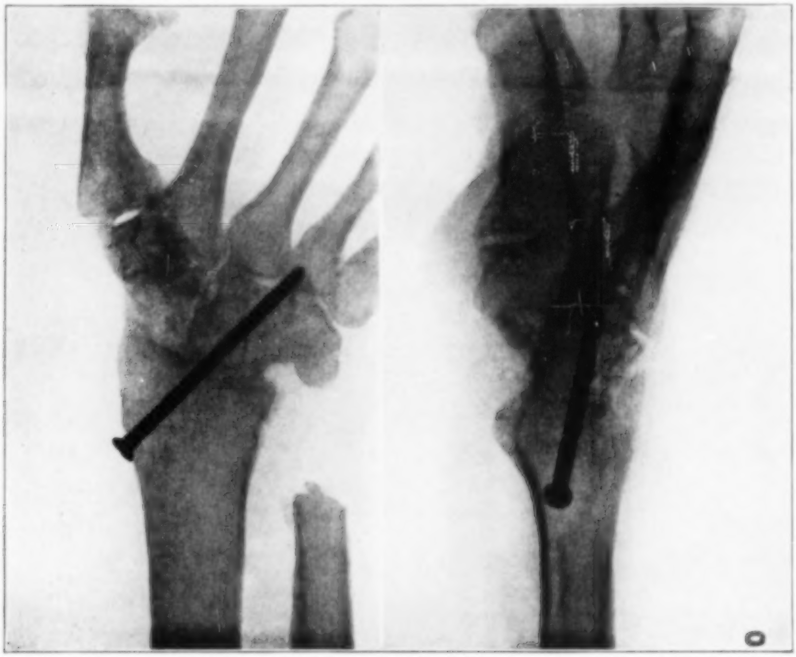

FIG. 2-E FIG. 2-F

Case 2. The final result after re-fusion.

It should be noted that in both Case 1 and Case 2 the screws are slightly too long, for the screw should not intrude on the carpometacarpal joint. In subsequent procedures, this fault has been corrected.

SUMMARY

This new method of arthrodesis of the wrist was devised to obtain rapid and certain fusion with a minimal loss of time and earning capacity and to attain and maintain a precise positioning of the hand.

The procedure consists essentially in resection of the proximal row of carpal bones, with fixation of the capitate to the radius by means of a screw. It has the advantages of apposing cancellous bones, with an intact blood supply, with positive internal fixation. Healing is not dependent upon any grafted bone.

The operation is recommended for routine fusions in non-tuberculous cases. It is preferred to arthroplasty because of the stability, freedom from pain, and the relatively slight disability which results.

Note: Appreciation is expressed to Dr. H. R. Conn for his helpful suggestions and encouragement.

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OSTEOMYELITIS IN INFANTS *

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The incidence and severity of acute hematogenous osteomyelitis have decreased strikingly in the past fifteen years, first because we have a better knowledge of general treatment of the sick child, and second because of the development of antibiotics. However, as the incidence in infants under the age of one year has not decreased, the disease in the infant is relatively more common and more important than in former years.

The purpose of this paper is to point out the shift in age incidence of acute hematogenous osteomyelitis to the younger group, to discuss the problem of early diagnosis, to call attention to the crippling deformities which occur in infancy, and to try to determine what changes in present methods of treatment will diminish this disability.

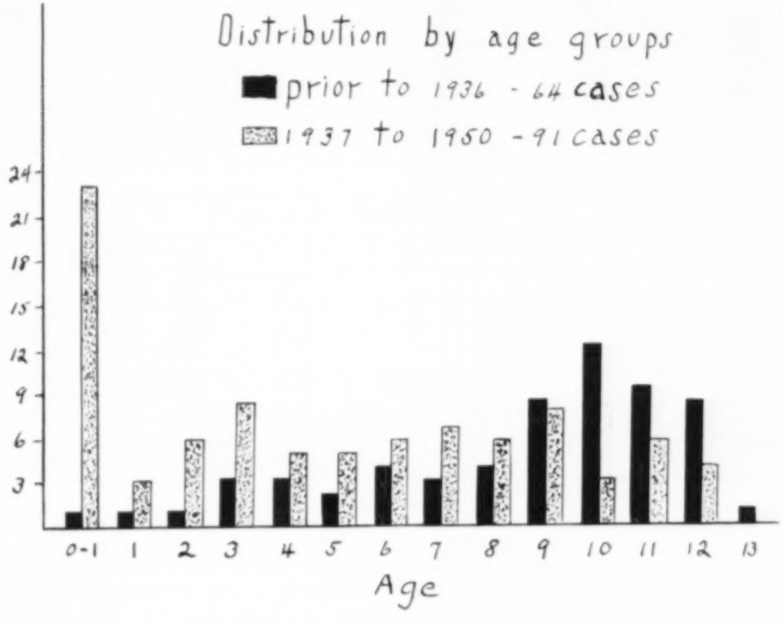

CHART I

Distribution by age groups. A series of ninety-one cases treated from 1937 to 1950 is compared with a series of sixty-four treated prior to that time and reported by Wilson and McKeever in 1936. In the earlier group the highest incidence was in the ten-year-old age group, in the later group the peak incidence was in the group less than one year old.

Green and Shannon differentiated osteomyelitis in infants from that in older children. Streptococcus was most frequently encountered in their series. They also pointed out that the infant's spongy, vascular bone with thinner cortex and looser periosteum favors early spontaneous decompression and healing. Dickson emphasized that a distinction must be made between transient bacteraemia with localized bone infection and true septicaemia, which produces abscesses—usually multiple abscesses—in viscera as well as in bone. It has been stated repeatedly that, if the patient survives the initial infection, residual deformity is unusual, except when there is a complicating pyarthrosis of the hip, as in the cases reported by Badgley and his associates, Nicholson, Einstein and Thomas, and Harmon and Adams. More recently Greengard, Self, and Beerman have stressed the importance of general systemic care almost to the exclusion of surgical treatment.

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* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 31, 1951.

The findings in the present study are in accord with some of the earlier reports, but are at variance with others.

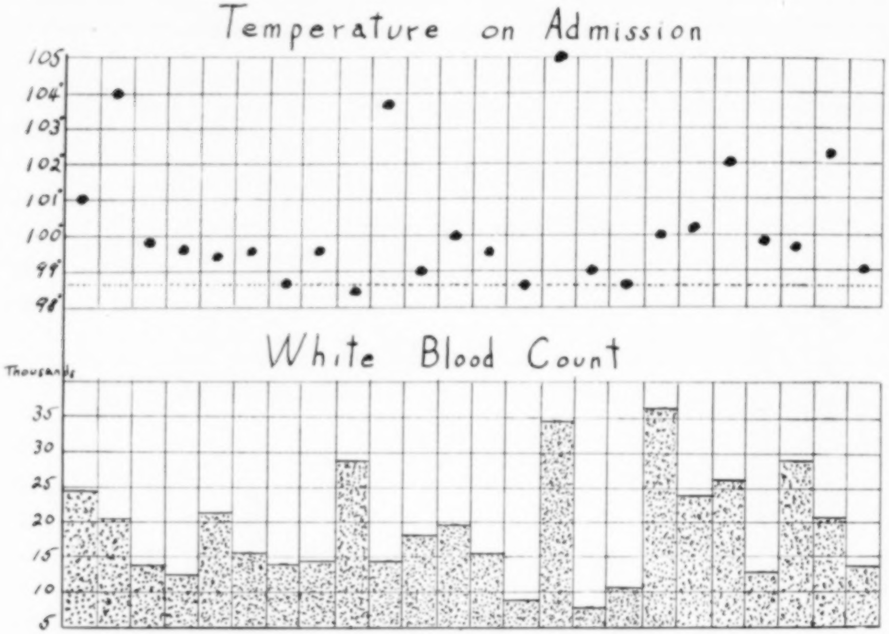

CHART II

Temperature and white blood count of each patient on admission to the hospital.

In the sixteen-year period from 1934 to 1950, thirty-five infants under the age of one year were treated for hematogenous osteomyelitis at the Children's Hospital of Los Angeles. A bacteriological diagnosis was made in twenty-five; only these cases are considered in this report.

AGE INCIDENCE

The youngest patient was fourteen days old, the oldest nine and one half months. Thirteen were under one month of age on admission, ten were from one to two months old. The remaining two were eight and nine and one-half months, respectively. Eighteen were male, seven female.

In a series of sixty-four cases of acute hematogenous osteomyelitis from this Hospital reported by Wilson and McKeever in 1936, the greatest incidence was at age ten years, and only one patient was under one year of age. Tabulation of cases treated since that time shows that the greatest incidence is now in the age group of less than one year (Chart I). This shift in age incidence may be due, first to the common use of antibiotics in treatment of primary infections in older children, and second to the lack of resistance of the newborn to pyogenic infections.

SYMPTOMS

In all but two cases, the infant was in good general condition and well nourished when admitted to the hospital. He was usually irritable and cried when the affected extremity was moved. The temperature was seldom over 100 degrees, and many had no fever at all (Chart II). The white blood count was usually elevated, ranging from 8,000 to 36,000. In the majority of cases there had been no recognized antecedent infection. Five had a moist or infected umbilicus, two had diarrhoea, and three had a history of pneumonia, cellulitis of the face, and chronic discharge from one eye, respectively.

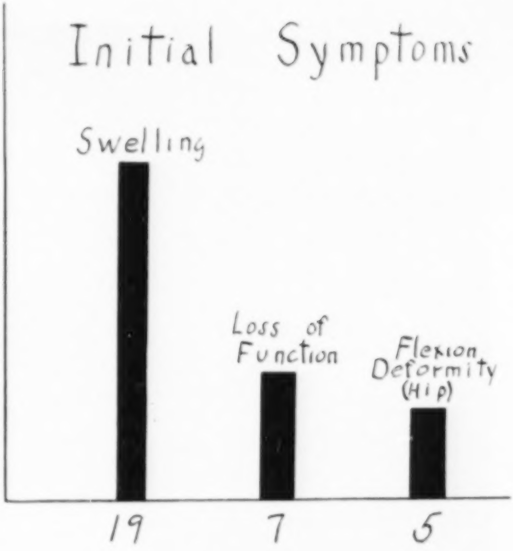

Chart III
Initial symptoms.

The outstanding local symptoms were swelling and loss of function of an extremity (Chart III). In some there was flaccidity, particularly in lesions of the proximal end of the humerus, which led to a diagnosis of poliomyelitis in one case and of birth palsy in another. Lesions of the proximal end of the femur were manifested by painful flexion deformity of the hip. Loss of function of the lower extremity and tenderness led to a mistaken diagnosis of scurvy on several occasions. In most instances early diagnosis was not made, either because the baby was not taken to a physician until

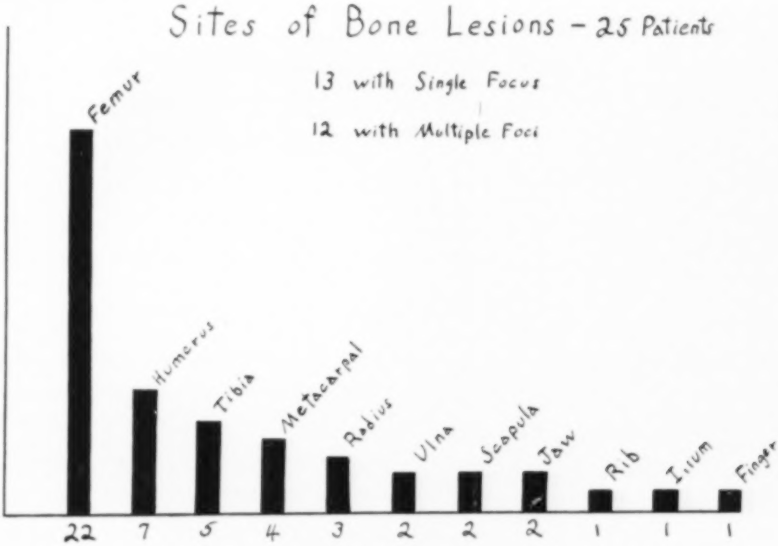

Chart IV
Sites of bone lesions. There were fifty known foci in bone.

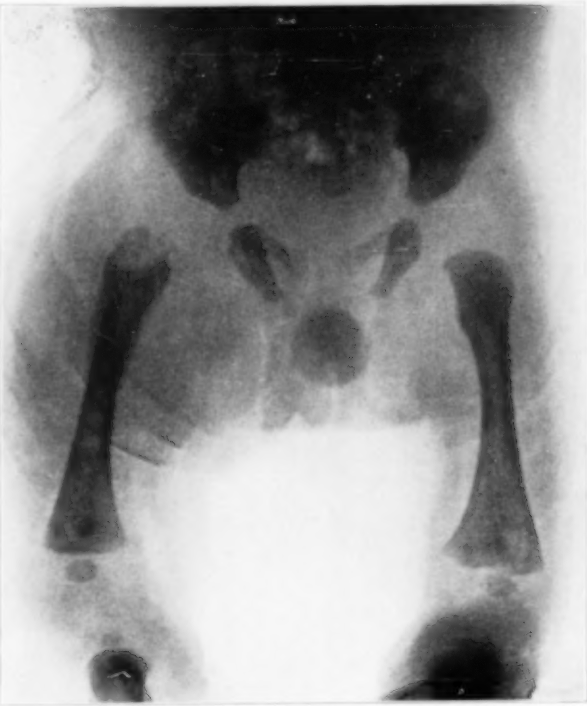

FIG. 1-A

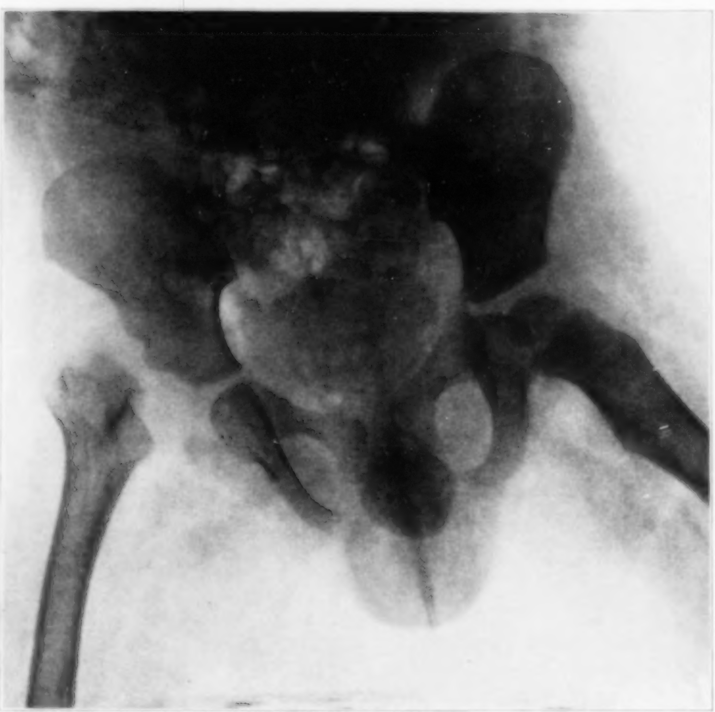

FIG. 1-B

Fig. 1-A: Case 22. A. U., twenty-three days old. X-ray of pelvis made in December 1948, showing osteomyelitis of proximal end of femur with pathological dislocation of the hip.

Fig. 1-B: X-ray of pelvis made in June 1950, when the patient was seven months old. The head of the femur is missing and the neck is deformed. The hip is dislocated.

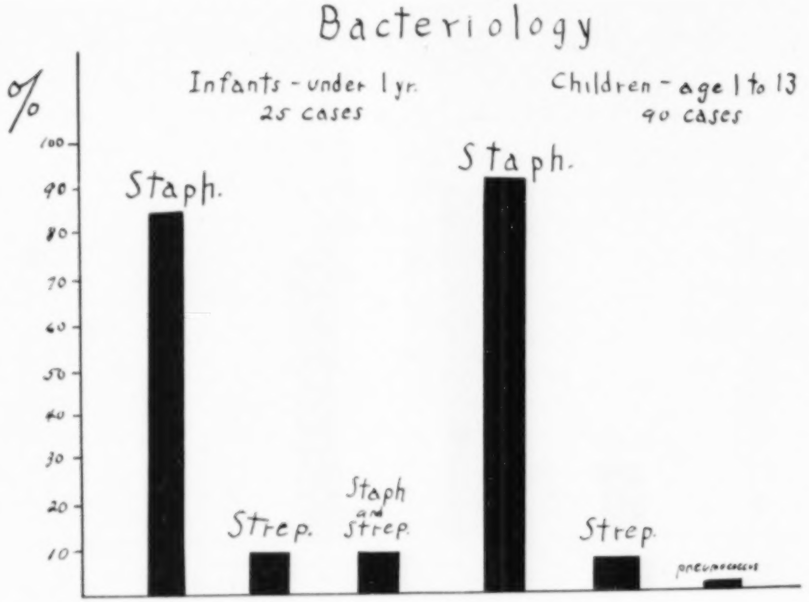

CHART V

Comparison of the relative frequency of staphylococcic and streptococcic infection in this group of infants with a group of older children shows that Staphylococcus predominates in both.

some days after onset, or because frequently the true nature of the illness was not recognized at initial examination. A week or more often elapsed between onset of local symptoms and admission to the hospital, at which time there was roentgenographic evidence of advanced involvement of bone and disruption of the joint.

NUMBER AND LOCATION OF FOCI

In thirteen cases a single bone was involved. The total number of known foci in bone was fifty. Twenty-two were in the femur; sixteen of these were at the proximal end, with associated pyarthrosis of the hip in eleven cases. Seven were in the humerus, six of these being in the proximal end, and five were in the tibia (Chart IV).

BACTERIOLOGICAL DATA

The infecting organism was isolated in all cases, either from the local lesion, from blood culture, or from both. Staphylococcus in pure culture was isolated in twenty-one cases (84 per cent.); of these one was *Staphylococcus albus*, one *Staphylococcus citreus*, and the other nineteen *Staphylococcus aureus*. Sixteen were classified as hemolytic. Streptococcus in pure culture was isolated in two cases (8 per cent.). In two cases both Staphylococcus and Streptococcus were found. For comparison, a review was made of the infecting organism found in a group of ninety patients, aged one to thirteen years, treated during the same period. Staphylococcus was isolated in 93 per cent. and Streptococcus in 6 per cent. Thus staphylococcic infection in this series was almost as frequent in infants as in older children (Chart V).

SPECIFIC THERAPY

Five of the early patients received no antibiotics. Three were treated with sulfonamides alone. All of the seventeen patients treated since 1944 have received penicillin,

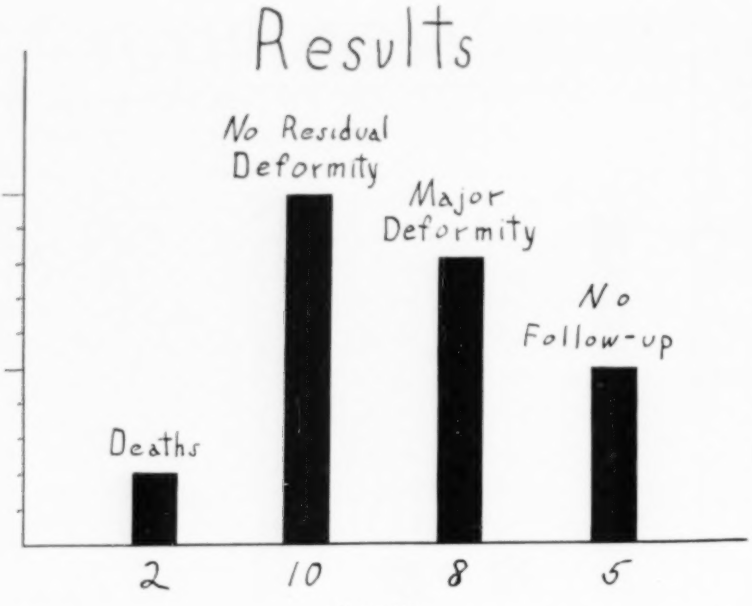

CHART VI

In 44 per cent. there was major deformity of a crippling nature.

alone or in conjunction with other antibiotics. The amounts of these drugs given were so variable, as was the stage of infection when treatment was started, that no conclusions can be drawn regarding optimum dosage. The two patients who were acutely ill on admission were given very large amounts of penicillin and sulfonamides and recovered. The first two patients in this series died, although neither had been acutely ill on hospital admission; they had received no antibiotics. There have been no fatalities since 1939.

RESULTS

The only chronic drainage was in a baby with osteomyelitis of the scapula which drained for sixteen months. There was no recurrent infection, nor any sequestration of bone. For five patients there is not sufficient follow-up data, either because the onset was too recent to evaluate the result or because they could not be traced. In ten cases (56 per cent.) there was complete recovery except for slight bone thickening or shortening. The shortest follow-up in this group was seven months, the longest five years. In eight cases (44 per cent.) there was major deformity of a crippling nature resulting from destruction of the epiphyseal plate, or of the epiphysis with disruption of the joint (Chart VI). The shortest follow-up in this group was nineteen months, the longest six and one-half years.

The hip joint became septic in eleven of the sixteen cases in which the proximal portion of the femur was involved. These patients were all treated by simple surgical drainage, usually followed by traction or application of a cast. In eight there was bone destruction in the metaphysis of the femur and pathological dislocation at the time when the first x-ray was made. One case could not be followed. All other hips that were found to be dislocated at the time they were drained are still dislocated, with residual deformity and with the head or head and neck of the femur absorbed.

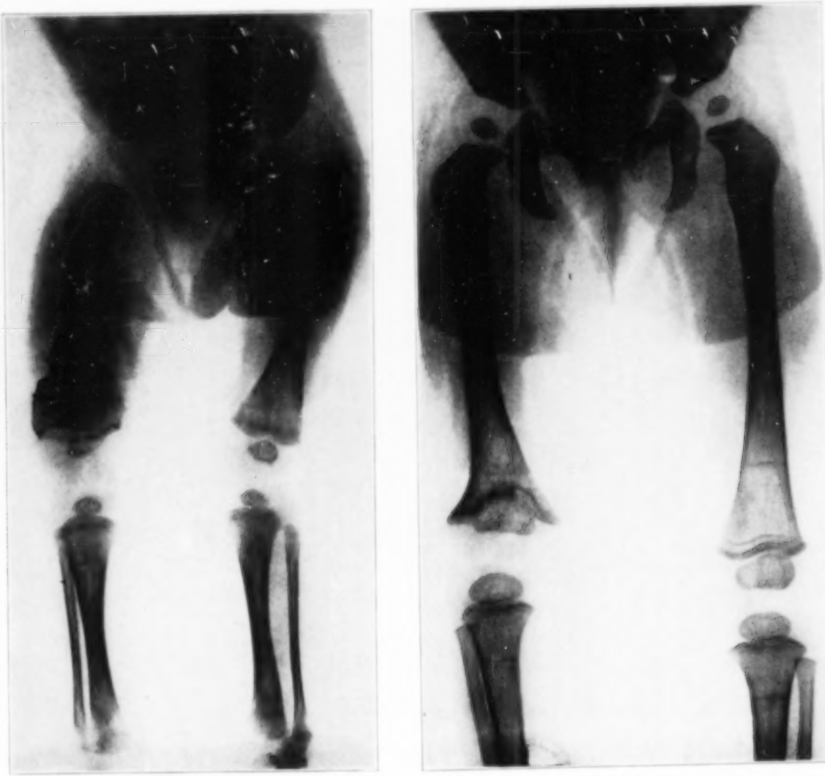

FIG. 2-A FIG. 2-B

Fig. 2-A: Case 23. P. V., thirty-three days old. X-ray made on admission in September 1949. There is a destructive lesion with periosteitis of the distal end of the right femur. A diagnosis of scurvy had been made previously.

Fig. 2-B: X-ray made thirteen months later in October 1950 shows distortion of the metaphysis and epiphysis and shortening of the femur by two centimeters.

CASE REPORTS

CASE 22. An infant, A. U., is typical of the group with hip-joint involvement. He was admitted to the hospital at age twenty-three days, in December 1948. The mother stated that when she took the baby home from the maternity hospital on the eighth day, the right lower extremity was somewhat swollen and red, and he did not move it as well as the left. She also noted that there was bloody drainage from the umbilicus, but there was never any pus. At admission the baby was found to be well developed and nourished, and not acutely ill. The temperature was 99.8 degrees and the white blood count was 12,450. There was swelling and induration of the upper half of the right thigh and diminished active motion. The roentgenogram made at that time (Fig. 1-A) showed a destructive lesion of the proximal portion of the femur, with dislocation of the hip. Penicillin, 240,000 units daily, was given for twenty-one days. The hip joint was incised on the third day and pus was released, from which was cultured both hemolytic *Staphylococcus aureus* and *gamma streptococcus*. Traction was used with increasing abduction but was discontinued after one month because the hip was still dislocated. At that time the wound was healed. At age seven months, the hip presented a flexion, abduction, and external rotation deformity with shortening of the extremity of three centimeters. Open reduction was attempted at this time. The femoral head was found to be about six millimeters in diameter, and there was a small rudimentary femoral neck. There was little fibrous tissue in the acetabulum. The head was easily replaced into the large acetabulum by simple internal rotation of the femur and the position was held by casts. However, a roentgenogram made at age eighteen months showed a broad femoral neck riding above the acetabulum, and no head was visible (Fig. 1-B). At that time, a reconstruction was performed, but it is too early to evaluate this procedure.

TABLE I

DATA ON ALL CASES ON WHICH THIS REPORT IS BASED

Case	Year	Age	Sex	Symptoms	Duration before Admission (days)	Temperature and White Blood Count on Admission		Cultures		Organism	Foci in Bone	Late Clinical Result	Roentgenographic Appearance at Follow-up Examination	Period of Follow-up
								Blood	Pus					
1 M.T.	1934	7 weeks	M	Swelling and inability to move lower extremity. Cried when moved	3	101	24,400	No	Yes	*Staph. aureus*	Femur (proximal end)	Miliary abscesses in viscera Died 3 weeks later		Died
2 J.H.	1935	5 weeks	F	Nasal discharge Diarrhoea (Abscesses developed after admission to hospital)	7 4	104	20, 500	Yes	No	*Staph. aureus*	Multiple	Septicaemia Multiple abscesses in extremities and viscera Died 17 days later		Died
3 M.A.	1939	18 days	F	Discharge from eye Swelling of jaw and drainage	18 1	99.8	13,800	Yes	No	*Staph. aureus*	Jaw			No follow-up
4 F.C.	1939	15 days	M	Redness, swelling of breast (Swelling of hand seven days after admission)	2	99.6	12,300	No	Yes	*Staph. aureus*, hemolytic	Metacarpals (2)	Full range of motion Wounds healed	No sequestrum	4½ mos.
5 J.W.	1939	7 weeks	M	Swelling of leg		99.4	21,600	No	Yes	*Staph. citreus*	Tibia (proximal end)			None
6 R.S.	1940	3 weeks	M	Infected umbilicus Redness, swelling of wrists (Other symptoms developed in hospital)	3	99.6	15,700	Yes	Yes	*Staph. aureus* hemolytic	Femur (proximal end) Radius (distal end) Ilium	Slight limp Shortening of 1.5 centimeters	Separation epiphysis of head of femur Shaft displaced laterally	19 mos.
7 A.J.	1942	8 mos.	M	Pneumonia Burns from hot-water bottle Swelling of wrists	25 25 9	98.6	14,100	Yes	Yes	*Beta strep.*, hemolytic	Ulnae (distal ends of both)	No residual deformity	Hypertrophy of ulnae with slight deformity of distal ends	15 mos.
8 S.T.	1944	24 days	F	Swelling, redness of palm Swelling of knee	7 1	99.6	14,600	No	Yes	*Staph. aureus*, hemolytic	Femur (distal end)			None

(Table I—*Continued*)

9 R.R.	1944	29 days	M	Swelling of finger 14 Swelling of hand, thighs, shoulder just before admission	98.4	28,500	Yes	Yes	*Staph. aureus*, non-hemolytic	Finger Femora (proximal end in both) Femur (distal end) Humerus (proximal end)	Marked lumbar lordosis Waddling gait Left leg 3 centimeters short Left arm 3 centimeters short Restriction of flexion in right knee	Distortion of proximal ends of both femora. Hips dislocated Distortion distal end of right femur, epiphysis deformed Right femur 4 centimeters short	6½ yrs.
10 T.I.	1944	32 days	F	Cellulitis of face 23 Restriction motion of arm 6 Swelling over scapula 2			Yes	Yes	*Staph. aureus*, hemolytic	Scapula	Drained for 16 months Full motion of shoulder No recurrence	Minimal residual deformity of scapula No sequestrum	5 yrs.
11 S.D.	1946	9½ mos.	M	Fever 30 Kept lower extremities flexed Pain on passive motion 24	103.6	14,500	Yes	No	*Staph. aureus*, hemolytic	Femur (proximal end) Femora (distal end in both) Tibia (proximal end)	No residual deformity	No deformity	3½ yrs.
12 C.S.	1946	17 days	M	Hip held in flexion 10 Pain on passive motion 10	99	16,900	Yes	Yes	*Staph. aureus*, hemolytic	Femur (proximal portion) Hip joint distended on admission	1 centimeter shortening Slight restriction of hip rotation No pain. No limp.	Considerable hypertrophy of femur	4 yrs.
13 J.A.	1946	26 days	M	Diarrhoea 14 (Multiple pyogenic foci developed after admission)	100	19,500	Yes	Yes	*Staph. aureus*, hemolytic	Femora (proximal end in both) Femur (distal end) Humeri (proximal end in both) Radius (distal end) (lung abscesses)	Flexion contracture in both hips, right knee, left elbow, shoulder Shortening of 4 centimeters in right lower extremity Radial deviation of hand	Distortion of both hips and right distal femoral epiphysis Disturbance of distal radial epiphysis, with deviation of hand Deformity of proximal portion of humerus	4¼ yrs.
14 P.G.	1947	24 days	M	Swelling of ankle 1 Lower extremity held flexed ½	99.6	15,600	Yes	Yes	*Staph. aureus*, hemolytic	Femur (proximal end)	No residual deformity	No deformity	16 mos.

(Table I—*Continued*)

Case	Year	Age	Sex	Symptoms	Duration before Admission (days)	Temperature and White Blood Count on Admission		Cultures		Organism	Foci in Bone	Late Clinical Result	Roentgenographic Appearance at Follow-up Examination	Period of Follow-up
								Blood	Pus					
15 C.H.	1948	2 mos.	M	Vomiting, irritability Swelling of ankle	5 2	98.6	8,850	Yes	No	*Staph. aureus*, hemolytic	Tibia (distal end)	No residual deformity	No deformity	10½ mos.
16 V.F.	1948	37 days	F	Swelling over chest Swelling of thigh	23 1	105	34,650	—	Yes	*Staph. aureus*, hemolytic, and *gamma strep.*	Humerus (proximal end) Rib Femur (proximal end; hip dislocated)	2.5 centimeter shortening of lower limb Hip unstable Walks with limp Late open reduction unsuccessful	Hip dislocated Head, neck of femur missing	2¼ yrs.
17 T.A.	1948	2 mos.	M	Septicaemia at age 6 days treated with large doses of penicillin and streptomycin Loss of function of arm	 3	99	7,850	—	Yes	*Staph. albus*	Femur (proximal end) Humerus (proximal end) (Destructive lesions present on admission)	Full range of motion, no deformity	Pelvis normal Slight deformity of proximal end of humerus	23 mos.
18 G.G.	1948	6 weeks	M	Swelling of hip Loss of function	7 7	98.6	10,500	No	Yes	*Staph. aureus*, hemolytic, and *Staph. albuso*	Femur (proximal end) (Hip dislocated on admission. Destructive lesion in femur)			None
19 J.M.	1948	24 days	M	Loss of function of arm Swelling of wrist Swelling of ankle Swelling of chest	13 12 10 8	100	36,200	Yes	Yes	*Staph. aureus*, hemolytic	Humerus (proximal end) Tibia (proximal end) Radius (distal end)	No limp Arrested growth of distal end of radius with progressive radial deviation of hand	Humerus normal Knee essentially normal Shortening of radius, distortion of epiphysis	22 mos.
20 J.D.M.	1948	17 days	M	Anorexia and irritability Swelling right arm Swelling left knee Swelling left shoulder (Umbilicus inflamed)	12 3 1 ½	100.2	23,850	Yes	Yes	*Beta strep.*	Tibia (proximal end) Scapula	No deformity	Tibia and scapula appeared normal	24 mos.

Table I (*Continued*)

21 D.C.	1948	14 days	M	Hip held in flexion 8 Swelling 2	102	26,500	Yes	Yes	*Staph. aureus*, hemolytic	Femur (proximal end) (Hip dislocated on admission)	2 centimeters shortening, limp Restriction of hip motion Late open reduction of hip unsuccessful	Hip dislocated Head missing, neck rudimentary	23 mos.
22 A.U.	1948	23 days	M	Child did not move right lower limb 15 Swelling and redness of limb 15 (Bloody discharge from umbilicus at age 8 days)	99.8	12,450	—	Yes	*Staph. aureus*, hemolytic, and *gamma strep.*	Femur (proximal end) Hip dislocated on admission	Lower limb short and hip dislocated Late open reduction unsuccessful Reconstruction done June 1950 —result not yet determined	June 1950: Head missing Neck broad and short Hip dislocated Nov. 1950: Reconstruction has been done	22 mos.
23 P.V.	1949	33 days	F	Would not move right limb and cried when touched 19 Swelling right hand 12 Swelling of jaw 10 (Thin bloody drainage from umbilicus on admission)	99.6	28,450	Yes	Yes	*Staph. aureus*, hemolytic	Femur (distal end) Humerus (distal end) Two metacarpals Mandible	2 centimeters shortening of lower limb 10 degrees valgus of knee, slight anteroposterior instability	Distortion of metaphysis and distal epiphysis of femur, with 2 centimeters shortening	15 mos.
24 D.F.	1950	39 days	M	Fever, irritability 1 Held hip in flexion 1	102.4	21,000	Yes	Yes	*Staph. aureus*, hemolytic	Femur (proximal end) Hip joint distended on admission	No deformity	No deformity	7 mos.
25 W.W.	1950	19 days	F	Swelling of thigh 1	99	17,000	—	Yes	Staph., hemolytic	Femur (proximal end) Hip joint distended on admission	Shortening of 0.5 centimeters Full range of motion	Neck of femur small and in varus, points into acetabulum No head visible	7 mos.

Case 5 (J.W.) reported through courtesy of J. Norton Nichols, M.D.
Case 8 (S.T.) reported through courtesy of Samuel S. Mathews, M.D.
Case 10 (T.I.): Patient first admitted to Children's Hospital, Denver, Colorado.
Case 18 (G.G.) reported through courtesy of J. Vernon Luck, M.D.
Cases 9 (R.R.), 12 (C.S.), and 13 (J.A.) were included in a previous report from Children's Hospital, Los Angeles, California by Charles G. Hutter, M.D.
Case 25 (W.W.): Patient first admitted to Salt Lake County General Hospital, Utah.

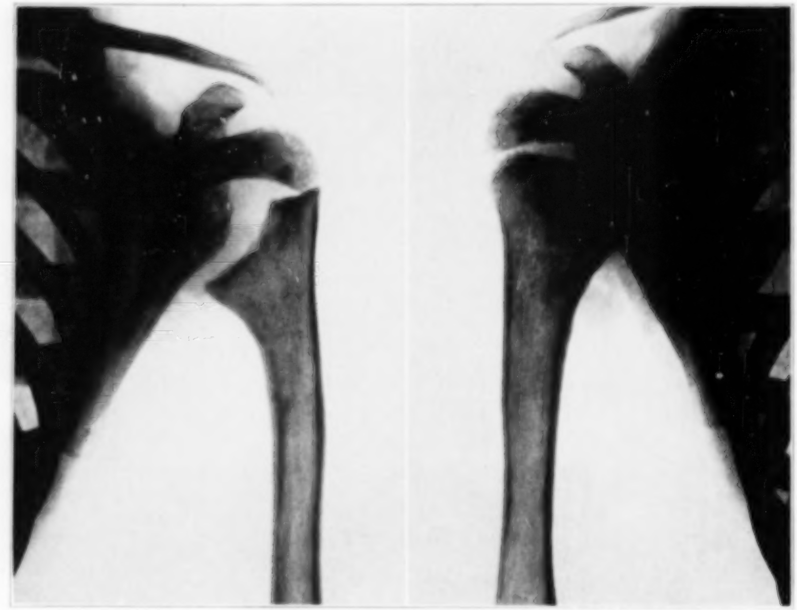

FIG. 3-A FIG. 3-B

Figs. 3-A and 3-B: Case 9. R. R., four and one-half years old. The roentgenogram shows partial destruction of the proximal end of the left humerus. The right humerus, essentially normal, is shown for comparison.

In pyarthrosis of the hip the degree of destruction in the joint and epiphysis and the resultant permanent disability are directly proportional to the delay in instituting surgical drainage.

The distal end of the femur was infected in six instances. The result in one is not known. In three patients, the disease process in the distal end of the femoral metaphysis resulted in pronounced deformity of the epiphysis and growth disturbance.

CASE 23. P. V. illustrates the result of infection of the distal end of the femur. The baby was born by easy breech delivery at full term. At age of two weeks it was noted that she would not move her right limb and cried when touched. A diagnosis of scurvy was made. A week later the right hand swelled, and two days after this, the left mandible. The infant was admitted to the Children's Hospital at age thirty-three days. She was crying and irritable but not acutely ill; temperature was 99.6 degrees, white blood count, 28,450. The right knee, right hand, and left mandible were swollen. There was a thin, bloody discharge from the umbilicus. The abscess of the hand was incised and from this pus, as well as from blood culture, hemolytic *Staphylococcus aureus* was isolated; 400 milligrams of aureomycin daily was given for forty days. Initial x-rays showed a destructive lesion in the distal portion of the right femur (Fig. 2-A). Three months later there was irregularity and deformity of the distal end of the femur and shortening. At re-examination one year later, there was one-half inch shortening of the right lower extremity, and valgus deformity of the knee of ten degrees. Roentgenograms show distortion of the metaphysis and epiphysis, and the involved femur is two centimeters shorter than the opposite femur (Fig. 2-B).

Less deformity resulted from the six cases of infection of the proximal end of the humerus. In two of these patients there is shortening due to epiphyseal destruction, but good motion remains.

CASE 9. R. R. had multiple bone involvement; one of the foci was in the proximal end of the humerus. He was admitted in April 1944 at the age of twenty-nine days, acutely ill with septicaemia from the culture of which *Staphylococcus aureus* was grown, and there were foci of osteomyelitis in the proximal ends of both femora, distal end of right femur, proximal end of left humerus, and right ring finger. All of the involved joints now show residual deformity. There is shortening of the left humerus but a full range of motion of the shoulder (Figs. 3-A and 3-B).

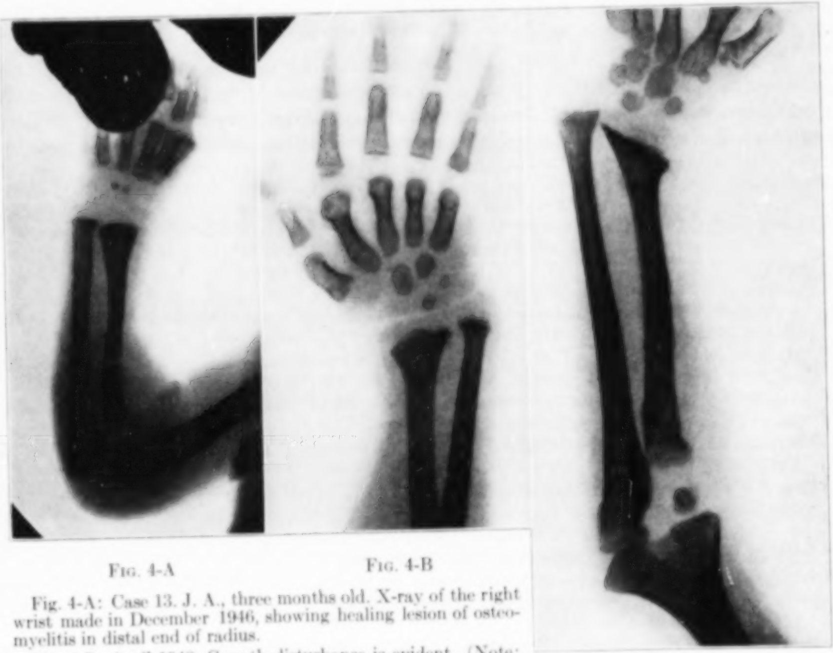

Fig. 4-A

Fig. 4-B

Fig. 4-A: Case 13. J. A., three months old. X-ray of the right wrist made in December 1946, showing healing lesion of osteomyelitis in distal end of radius.

Fig. 4-B: April 1948. Growth disturbance is evident. (Note: The three original roentgenograms were made of the right wrist of the same patient.)

Fig. 4-C

Fig. 4-C: March 1950. Three and one-half years after onset there is marked and progressive relative shortening of the radius and radial deviation of the hand.

The distal end of the radius was affected in three cases. In two of these, destruction of the epiphysis resulted in disturbance in direction of growth with progressive radial deviation of the hand.

Case 13. J. A. illustrates deformity due to involvement of the distal end of the radius. This infant was admitted to the hospital in October 1946, at age of twenty-six days, desperately ill with enterocolitis. Multiple foci of osteomyelitis became evident during the hospital stay. He remained critically ill for weeks, but recovered and is in good general health, although there is pronounced residual deformity in the hips, right knee, and right wrist. Serial roentgenograms of the right wrist show progressive shortening of the radius, with lateral tilting producing radial deviation of the hand (Figs. 4-A to 4-C).

CONCLUSION

1. Acute hematogenous osteomylitis in infants runs a rapid course. The correct diagnosis is often made late, after irreparable damage to joint components and growth centers has already taken place.

2. Normal temperature and absence of general reaction to infection are often misleading. This disease should be suspected if an infant becomes irritable and if swelling, tenderness, or loss of function of an extremity develop.

3. There is little controversy concerning the general treatment of the sick infant, but the present tendency is to pay too little attention to the local bone and joint lesion.

4. The intra-articular tension and lytic action of pyogenic exudate in pyarthrosis of the hip rapidly destroy cartilage, thus causing disruption of the joint, pathological dislocation, and serious growth disturbances which result in severe crippling.

5. In those dislocated hips which were later observed at open operation it was found

that internal rotation was necessary to place the remaining elements of the proximal end of the femur into the acetabulum.

6. The chief fault in present-day treatment is the tardiness of surgical drainage of localized abscesses, particularly when a hip joint is involved. Study of this series suggests that early surgical drainage, followed by traction in abduction and particularly with internal rotation, would have minimized absorption of cartilage and saved some of these hips.

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DISCUSSION

Dr. F. R. Wilkinson, Toronto, Canada: I find myself in agreement with almost everything Dr. Blanche has said, but I do disagree with him on the necessity for incision and drainage of joints filled with pus. In Toronto, following the teaching of Professor C. L. Starr, an ardent advocate of early operation, we had for several years operated on patients with acute hematogenous osteomyelitis and septic arthritis. Later, Dr. D. E. Robertson began to treat these patients conservatively, and since 1945 we have not done an early operation for these conditions—with no cause for regret.

Dr. Blanche cites three cases in which there was septic arthritis of the hips but no dislocation and in which he had good results, but these patients had an early diagnosis and, in my opinion, would have done just as well with traction, aspiration, and local and systemic penicillin. It is important to determine the sensitivity of the organism as soon as possible so that the most effective antibiotic may be chosen.

At the Hospital for Sick Children in Toronto, from January 1945 to December 1950, there were fifteen cases of acute suppurative arthritis and sixteen cases of acute hematogenous osteomyelitis in children under two years of age. In eight of the fifteen cases of suppurative arthritis the diagnosis was made early. Treatment by aspiration and local and systemic penicillin resulted in a full range of painless motion in the involved joints and no changes were evident on the roentgenogram. Of course, it is too soon to speak about end results.

Enthusiasm for surgery is best tempered by years of experience. Osteomyelitis, like tuberculosis, may be arrested but not cured. Dr. R. I. Harris has said that he is now treating patients with osteomyelitis at the General Hospital whom he had "cured" twenty-five years ago at the Sick Children's Hospital. In 1949, Dr. Gallie operated on a woman ninety-one years old and removed a sequestrum from her femur. She had had osteomyelitis at the age of eleven but had no further trouble until then; this represents an eighty-year follow-up.

In the infant, suppurative arthritis does not lead to ankylosis of the joint. I can give an example of a child with a free range of painless motion in the shoulder although the head and neck of the humerus have been destroyed. In one of the worst deformities I have encountered, the child had osteomyelitis of the femur at the age of six weeks and at the age of six years the affected extremity was five and one-half inches shorter.

Another baby was treated on the infant ward for nasopharyngitis and intestinal intoxication. Ten days after admission an abscess of the right heel was observed. On films taken to show the os calcis, our roentgenologist noted osteomyelitis of the left femur with septic arthritis and a pathological dislocation of the head. This method of making a diagnosis is not recommended—not even in Canada.

I believe that the story of these joints has been written when the patients reach us. As Altemeier [a] said, the results seem to vary with the duration of the disease at the time treatment was begun, with the dosage of penicillin used, and with the severity of the infection. When there is persistent toxaemia, drainage of the hip should be done, but I am inclined to agree with Ellis [b] that "once a joint has been widely opened and drained . . . the probability of useful movement is remote". The outlook is better when the operation is done early, but in most cases an early operation is not necessary. But surely the main point at issue and one which has been so well stressed is that an early diagnosis be made and adequate systemic and local treatment be started at once. As surgeons, we must continue to teach medical students, post-graduate surgeons, and general practitioners the vital importance of early diagnosis and to re-emphasize the fact that roentgenograms are useless for this purpose.

a. ALTEMEIER, W. A., and WADSWORTH, C. L.: An Evaluation of Penicillin Therapy in Acute Hematogenous Osteomyelitis. J. Bone and Joint Surg., **30-A:** 657-679, July 1948.

b. ELLIS, V. H.: Pyogenic Affections of Joints and Bones. *In* PLATT, HARRY: Modern Trends in Orthopaedics, p. 77. New York, Paul B. Hoeber, Inc., 1950.

DR. JESSE T. NICHOLSON, PHILADELPHIA, PENNSYLVANIA: The problem of early diagnosis of osteomyelitis is difficult, particularly in infants. They are on the pediatric or otolaryngological service because of a septicaemia, complicated by either otitis media, pansinusitis, cervical adenitis, pneumonia, parotitis, dermatitis, or a combination of two or more of these infections. Prior to chemotherapy and antibiotics, if the infant survived at all, surgical aid frequently was not requested until an abscess became apparent. At present a pointing abscess is rarely encountered, but advice of the orthopaedic surgeon is sought because the infant presents a swollen extremity, frequently mistaken for a thrombophlebitis, which he refuses to move and which is very sensitive to touch. It may not be until the child is ambulatory that a lump is noticed on a long bone, or a pathological fracture occurs as a residual from osteomyelitis, or that a limp, denoting a joint complication, is apparent.

With earlier diagnosis the crippling deformities mentioned by Dr. Blanche can be avoided. I believe in rest and support of involved extremities. To avoid fracture in osteomyelitis, plaster-of-Paris shells, waterproofed with cellulose acetone, are used. For pyogenic joints absolute immobilization is recommended in order to prevent dislocation or to maintain reduction, and to permit the synovial tissue to carry out its physiological function of combating bacteria.

I strongly advocate aspiration of pyogenic joints. I do not consider it difficult and I do not believe an anaesthetic is indicated. I believe in repeating the aspiration each day until no more purulent material is obtained, or until the culture of the material is reported negative. Aspiration is continued through a window in the cast. My criteria for open drainage are as follows:

1. If the patient's toxaemia remains unexplained after immobilization, if there is no septicaemia and no other foci of infection, and if there is adequate blood and fluid balance.

2. If the joint infection is of two weeks' duration, or if the aspirated material from the joint is of such consistency that suppuration is denoted.

In infants I think it is important to maintain reduction of the pyogenic hip in a position that holds both hips in full extension and abduction. In cases where dislocation has occurred it may take three double hip spicas, applied at intervals of five days to a week, to reach a "full split" position. Placing the infant face downward on the spica box so that the pelvic rest is against the pubis when the double spica is applied has facilitated reduction and prevented recurrence of the posterior subluxation.

If a dislocation of the hip has not been reduced by this method, an open reduction should be performed after the infection has been quiescent for some months and if the general condition of the infant permits.

It was taught by my predecessor at the Philadelphia Children's Hospital, the late Dr. William Jackson Merrill, that all joints recovering from infection should be protected from stress or weight-bearing until there is no muscle spasm and until the roentgenogram reveals normal density of bone. I order an ischial weight-bearing caliper brace when weight-bearing is permitted. In those cases in which absorption of the head and neck has occurred the caliper brace is continued until the rudimentary neck has developed a stable relationship with the acetabulum. Subtrochanteric osteotomies are then advised, in order to improve the range of hip motion and to correct the positive Trendelenburg sign. In three patients followed to adult life, in whom absorption of the capital epiphysis had occurred in infancy, there was shortening of the femur of only one and a quarter to one and a half inches.

DR. J. ALBERT KEY, ST. LOUIS, MISSOURI: I was very glad to see that Dr. Blanche found Staphylococcus to be the main offender, even in infants. I have never been able to confirm Dr. Green's work in Boston about Streptococcus being the chief offender in infants.

We used to treat these patients as surgical emergencies; now they are urgent candidates for chemotherapy because the infection in the bone or in the joint produces changes which are irreversible. There is still a

(*Continued on page 95*)

INTRAMEDULLARY FIXATION OF THE TIBIA

BY FREDERICK VOM SAAL, M.D., YONKERS, NEW YORK

Intramedullary fixation of the femur is now widely used. Internal fixation of the tibia is quite as satisfactory, although the technique is more difficult. It is, therefore, recommended only to those who are thoroughly familiar with the technique of open reduction of fractures.

Intramedullary pinning of the tibia has been done for both traumatic and pathological fractures, in osteotomies for non-union, and for congenital pseudarthrosis. In pathological conditions, pinning is contra-indicated if the area of involvement is within three and one-half inches of the knee or within two inches of the ankle joint.

Intramedullary fixation is never an emergency procedure and should be done only if there are optimum operating-room conditions and if the patient is completely prepared for major surgery. It should not be done if there is loss of skin, local or generalized infection, active tuberculosis, or severe circulatory disturbance.

Medullary nailing is indicated in fractures in the area between the mid-shaft and the juncture of the middle and distal thirds (Figs. 2-A and 2-B). At this level the canal is of uniform width and fixation is therefore most secure. The fracture line may be transverse or oblique. In comminuted fractures pinning should be used only if the two major fragments can be approximated, or if the fragments can be threaded on the pin like beads. For fractures in the upper third of the tibia it is better to apply a weight-bearing cast to the mid-portion of the thigh, with the knee in flexion (Fig. 3). For fractures below the proximal third, no external fixation is used other than elastic bandages to control oedema.

In patients over the age of fifty-five pinning should not be used unless the patient is unusually vigorous. In older people the cortex in the distal end of the tibia is often very thin and brittle and may easily shatter when the pins are inserted.

TECHNIQUE

The following apparatus is required: (1) an assortment of nested U-shaped pins, usually with a diameter of six and eight millimeters; (2) a solid metal driver; (3) two pieces of thin pipe which will slide over six-millimeter or eight-millimeter nails respectively; (4) an extractor; (5) a large rat-tail file; (6) a seven-millimeter reamer; (7) an awl; (8) gouges.

The fracture is exposed and the distal fragment is measured by means of a Steinmann pin inserted into the canal. One inch should be added for insertion into cancellous bone. The tibial tubercle is exposed through the same or a separate incision. A long oblique canal is cut into the tibia, the entrance hole into the medullary cavity being somewhat distal to the tibial tubercle. The hole should be to one side of the tubercle in line with the anterior ridge of the tibia. The hole should never be drilled into the tuberosity itself because the pin tends to come out the back of the bone and because there is too little tissue to cover the end of the pin.

The major difficulty lies in making the anterior cortex of the tibia, the roof of the canal, thin enough so that the pin will enter in the direction of the medullary canal and not at an angle to it (Fig. 1). This is best done with a seven-millimeter reamer or a rat-tail file. The canal should not be made too large or fixation will be lost.

Several nested pins should always be used to prevent rotation. They are driven simultaneously through the proximal fragment and several inches beyond the fracture before reduction. The pin tips are bent widely apart with small pieces of pipe and are then hammered back into the proximal fragment. The nearer the fracture to the ankle joint the greater the need for widely separating the nails (Figs. 4-A and 4-B). The frac-

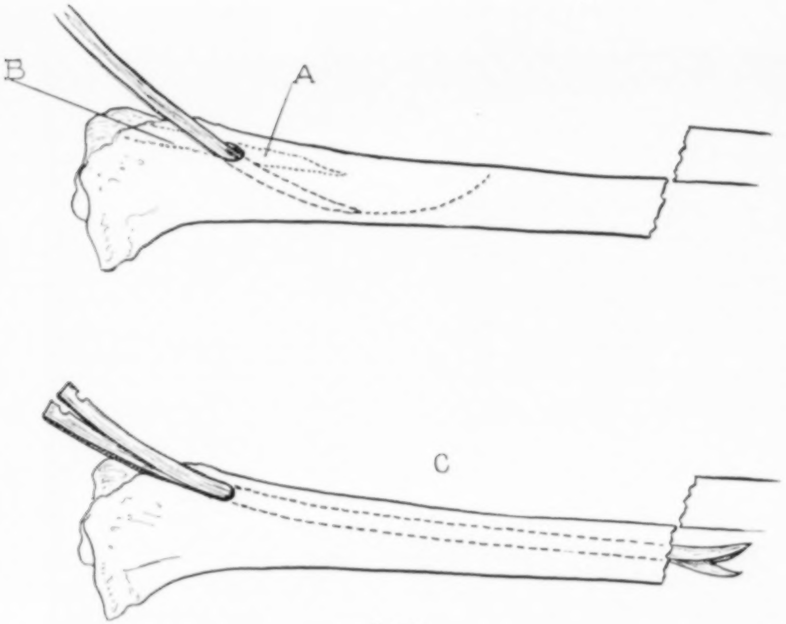

FIG. 1

Illustrating method of insertion of pin. *A*: The roof of the canal must be removed with a file or reamer. *B*: A long oblique canal is made with a gouge. *C*: The pins are driven beyond the site of the fracture, which has not been reduced, and are bent apart; they are then hammered back into the proximal fragment.

ture is reduced and the pins are driven into the distal fragment singly or together, whichever is easier. One anteroposterior roentgenogram of the ankle should then be made to show the position of the pin. The tips should be well within the cancellous bone and close to the joint. It is also important to bend the upper end of the pins forward a little, so that they will lie in the hole in the cortex and will not drop back into the medullary cavity.

All large comminuted fragments should be fastened to the shaft with ligature, suture, or screws, so that they will not subsequently be displaced by the free motion of the soft parts. If screws are used for split fractures or large fragments, they must always be inserted after the nails are in place (See Figures 5-A, 5-B, and 5-C).

Occasionally, in long oblique fractures, a circular wire is used to prevent angulation resulting from weight-bearing.

The fibular fragments should always be displaced. If this is not done, premature union of the fibula may cause distraction and non-union of the tibia. In the author's series a small amount of overlap of the fibula was found at follow-up examination in every case. If the fibula is intact, or if the fragments cannot be displaced, it should be osteotomized and a piece should be removed. This bone together with that removed from the tubercle, may be packed about the fracture site.

In non-union, it is usually unnecessary to resect the ends of the bones; they need only to be made square for apposition. The bone ends should be opened with an awl or a reamer. This is also necessary if there has been a previous fracture. The hole should not be made larger than the diameter of the pins. Additional bone must be packed about the site of non-union. If large strips are used they must be fastened to the tibia. This is most easily done with circumferential ligature or with screws (Figs. 6-A and 6-B).

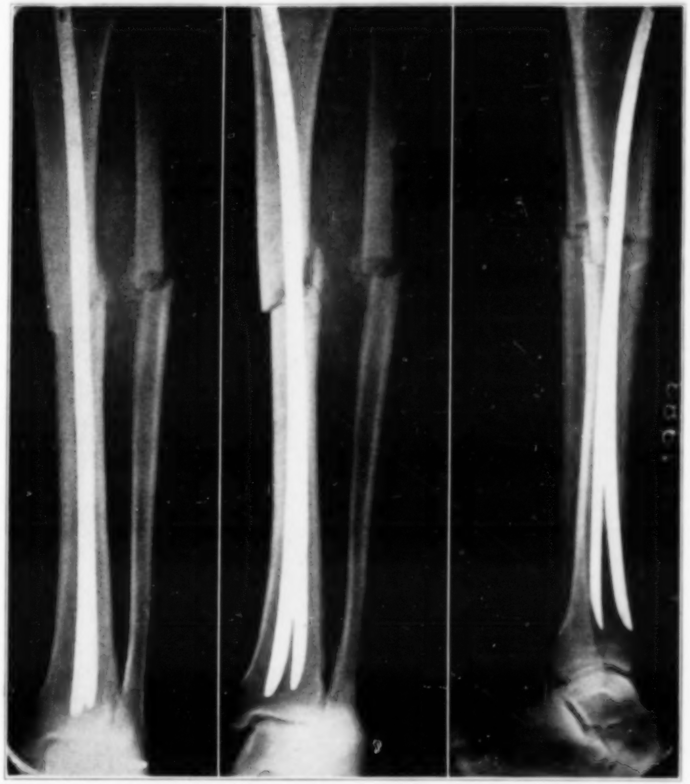

FIG. 2-A

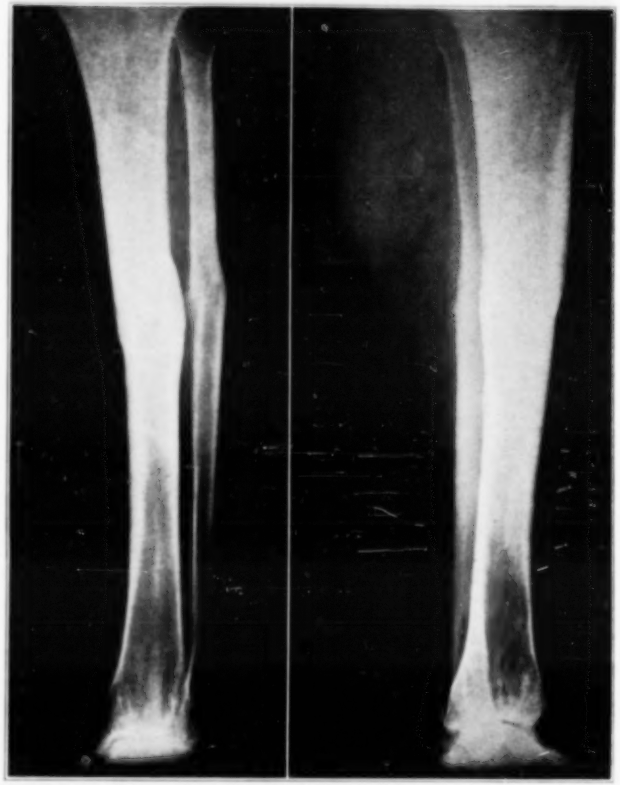

FIG. 2-B

Fig. 2-A: T. M., fifty-two years old. Roentgenogram made in June 1949, one month after pinning. The fracture in the mid-shaft of the right tibia does not need external support. The fragments of the fibula were not displaced, and a portion was therefore removed with a rongeur.

Fig. 2-B: Roentgenogram made in April 1951, twenty-two months after pinning. The pins had been removed fifteen months after reduction of the fracture.

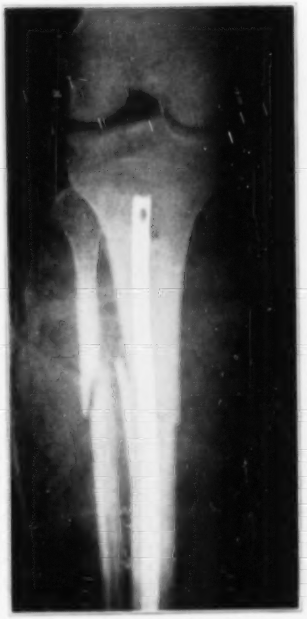

FIG. 3-A

Fig. 3-A: H. P., thirty-eight years old. Roentgenogram made in March 1948, after pinning. Note the lateral butterfly fragment and flaring of the canal at the fracture site. The patient had to have a cast for five weeks after he became ambulatory.

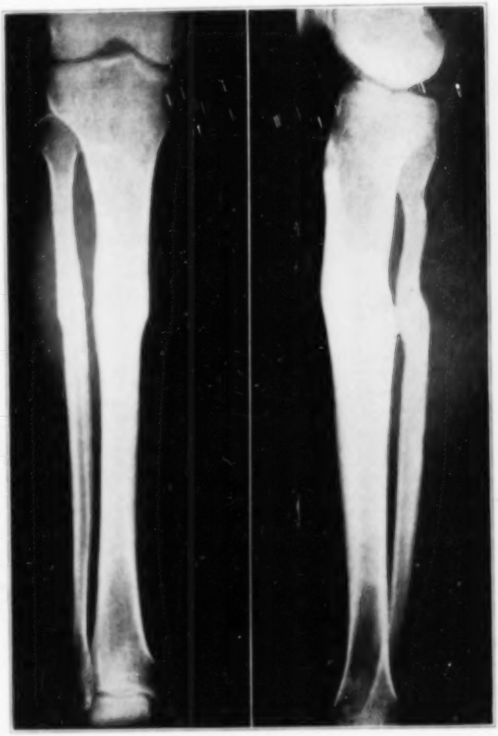

FIG. 3-B

Fig. 3-B: Roentgenograms made in April 1951, three years after pinning. There had been no change in the roentgenographic appearance of the leg for two years. The pins had been removed eight months after the operation.

AFTER-CARE

In leg injuries, the soft-tissue damage is often severe. Considerable attention must be paid to the circulatory status of the limb both before and after the operation. After operation, the limb should be kept in marked elevation for ten days except during ambulation. For two months after that the patient is required to keep the limb elevated while sitting. Weight-bearing is started as soon as the local circulation will allow, — that is, two to five days after the operation. Elastic or adherent elastic bandages are used routinely until swelling subsides.

Weight-bearing is an essential part of this treatment for four reasons:

1. A snugly fitted pin may easily hold the fragments apart exactly like a plate and produce non-union unless there is an impacting force.

2. All intramedullary pins become loose. Unless union is accelerated by weight-bearing, fixation may be lost before union occurs.

3. Impaction of the fragments decreases the possibility of rotation at the fracture site.

4. By eliminating the absorption zone through impaction, union is materially accelerated.

If plaster has been used, the cast should be changed after four days. A snug, almost unpadded cast is applied and fitted with a heel, and weight-bearing is started. After five or six weeks the plaster is removed and another roentgenogram is made. When plaster

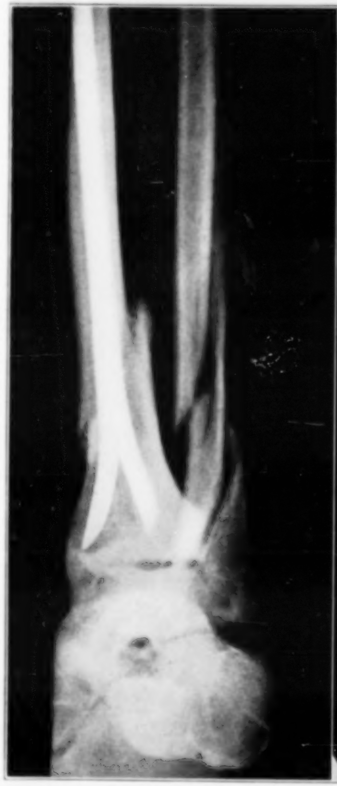

FIG. 4-A

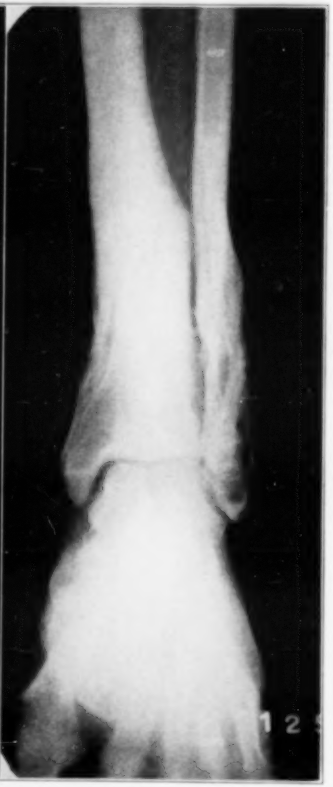

FIG. 4-B

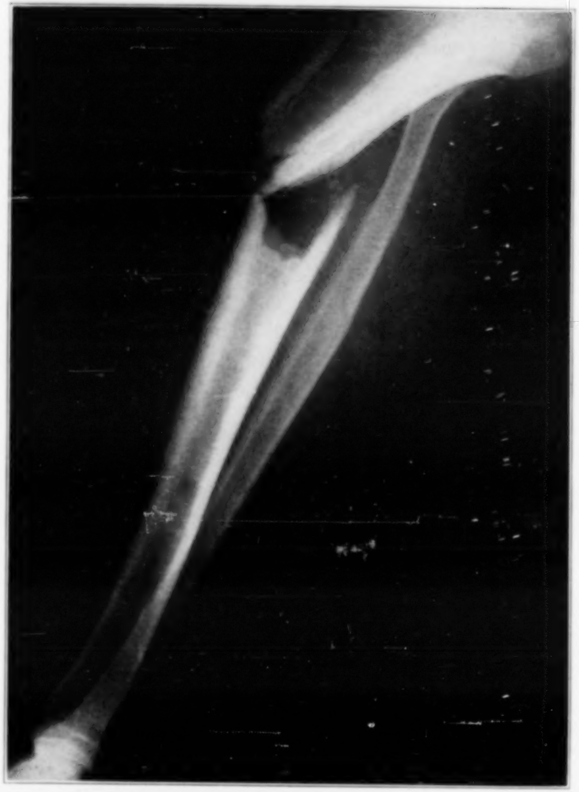

FIG. 5-A

Fig. 4-A: P. S., twenty-four years old. Roentgenogram made October 1949, after pinning. The severe fractures, two inches above the ankle, were adequately held by widely bent nails.

Fig. 4-B: Roentgenogram made in February 1951, sixteen months after pinning. The patient, who was a milkman, had returned to work five weeks after pinning.

Fig. 5-A: J. W., twenty-three years old. The patient had sustained a compound fracture; a large piece was split off from the proximal fragment.

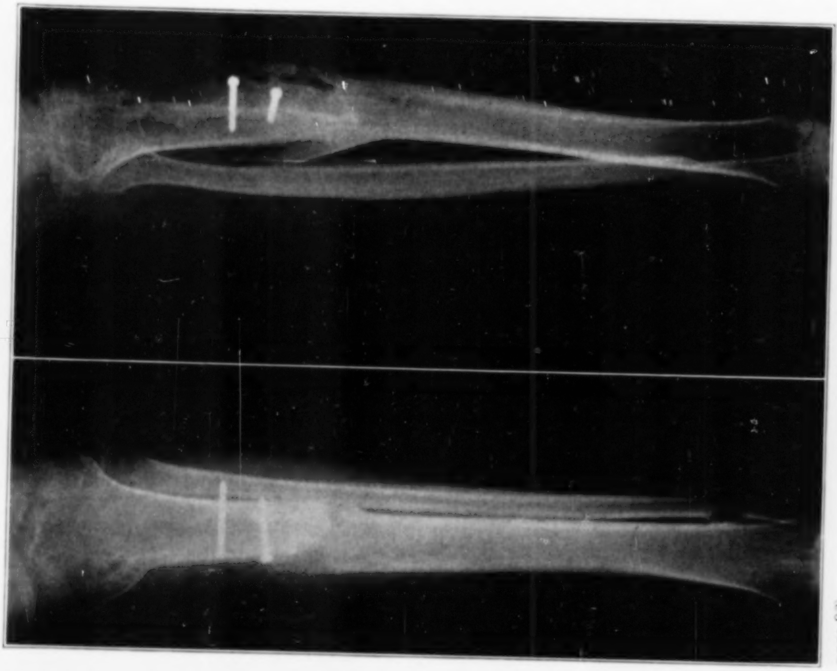

Fig. 5-C

(*Legends on page 92*)

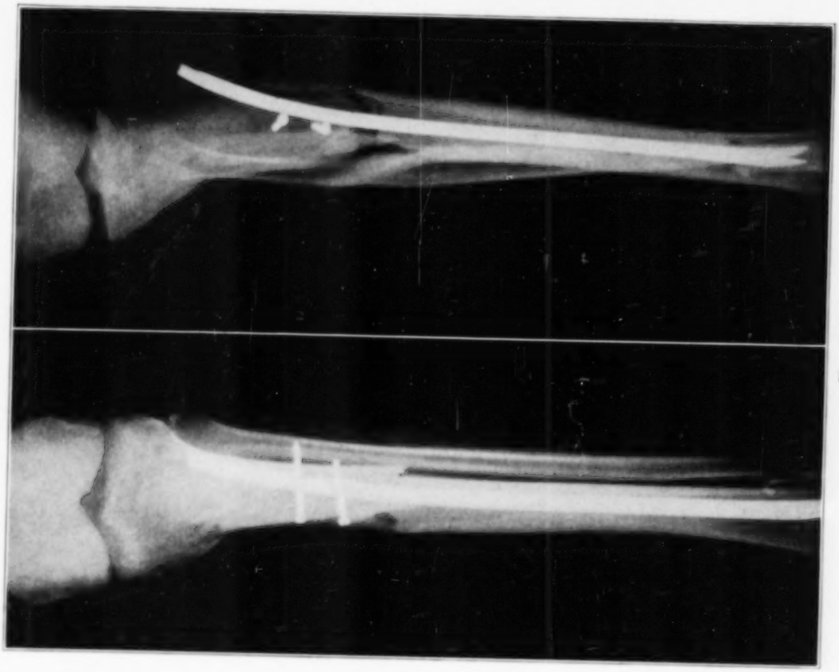

Fig. 5-B

Fig. 5-B: Roentgenograms made six weeks after the operation and after removal of the cast.

Screws must be inserted after the pins are in place; in this case the drill hit the pins (note the hole in the anterior cortex), and the screw could not be inserted.

Fig. 5-C: Roentgenograms made one year after pinning. The pins had been removed ten months after the operation. There was excellent function, and the patient was with the Infantry in Korea when last heard from.

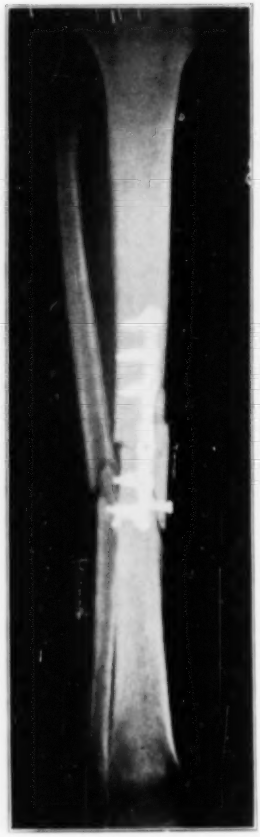

FIG. 6-A

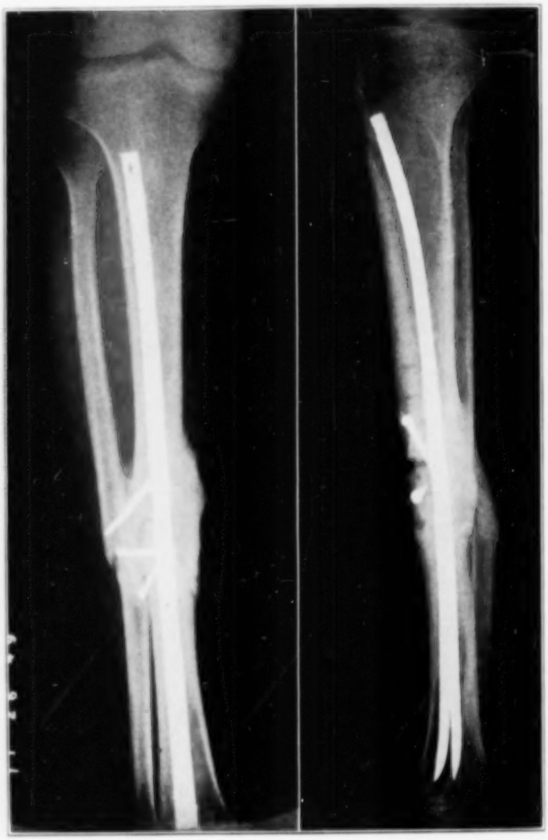

FIG. 6-B

Fig. 6-A: W. L., thirty-five years old. In this case there was infection and loss of skin. A skin graft was done, followed by pinning and fixation of the bone graft by screws. Weight-bearing was started one week later.

Fig. 6-B: Four months after the operation the roentgenogram revealed solid union.

has been used, one seldom sees the heavy collar of callus so common in other cases; interfragmentary healing, however, has usually progressed sufficiently after five weeks so that support may be discarded.

In general it is preferable to wait until interfragmentary union is complete and the pins are quite loose before an attempt is made to remove them; this is usually accomplished after about eight months.

The author has not used intramedullary fixation in fragilitas ossium or in marked osteoporosis. Other disease processes, such as Paget's disease, are not a contra-indication. In Paget's disease the intramedullary canal is occasionally obliterated and it is then necessary to ream out a new one.

In children, an open reduction is occasionally necessary because of soft-part inter-

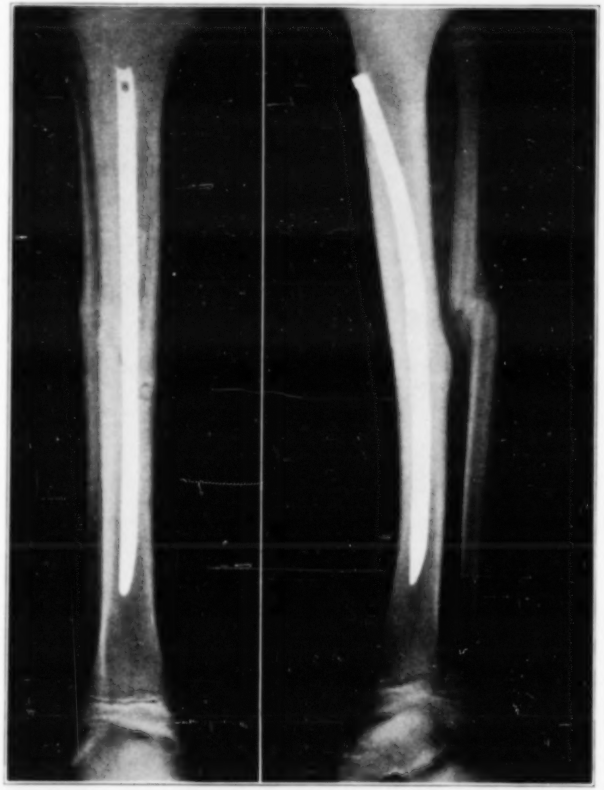

FIG. 7-A

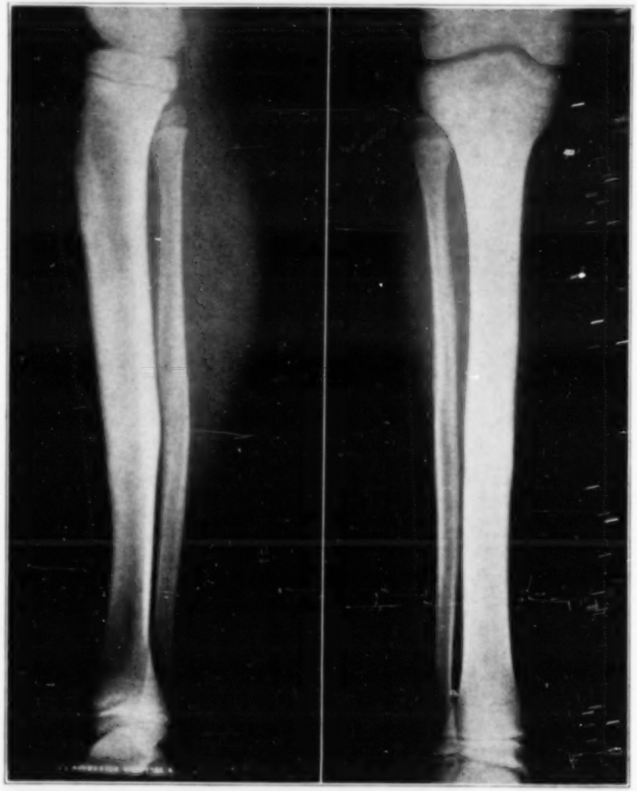

FIG. 7-B

Fig. 7-A: J. H., eight years old. Roentgenograms made seven weeks after pinning. An open reduction had been necessary because there was interposition of muscle. Note the short pin and the fibular overlap.

Fig. 7-B: Roentgenogram made at follow-up examination twenty months later. The leg lengths are equal and there is full function. The pin had been removed six months after operation.

position or because there is a compound fracture. In such cases pinning is very satisfactory. Usually only one pin is necessary; this should not reach the epiphysis. Fixation is adequate because in a child the canal is filled with sturdy cancellous bone (Figs. 7-A and 7-B).

RESULTS

Thirty-four tibiae have been pinned, of which twenty-six have been followed from one to four years, with an average follow-up period of nineteen months. Union was complete in all cases and in no case was healing delayed. At six weeks union was secure enough to allow normal activity in all patients with fractures and all those on whom osteotomies had been performed. Resumption of normal activity was later in those patients with non-union, but in none was it later than three months.

Non-union of the fibula occurred in five of the twenty-one cases in which resection was done. This failure of fusion in the resected bone caused no difficulty. The ankles were stable and the limbs painless.

Roentgenograms revealed slight fibular overlap in all cases, although in twenty-two there was no clinically measurable shortening. It is for this reason that adequate resection of the fibula is so important that the occasional case of non-union may be overlooked. Four patients, all with moderately comminuted fractures, had shortening of from one-half to one inch. Three patients had slight limitation of knee flexion. Extension was complete in all. In four patients there was also slight limitation of ankle motion.

There was virtually no atrophy at any time in most of the cases. However, in all patients who had also had a plaster cast, atrophy of both thigh and calf developed. This gradually disappeared in from three to ten months. No circulatory difficulties were encountered. Two patients had severe varicoses and high saphenous ligations were done as a prophylactic measure five or six days after reduction of the fracture.

Infection occurred in two cases, early in one and late in the second. In the latter a slight intermittent discharge developed from a sinus over the fracture six months after pinning. The discharge promptly disappeared after the pins had been removed, at which time there was found to be erosion on the adjacent surfaces of the two pins.

Infection also developed in the only case in which the author attempted closed reduction and blind pinning; this may have been due to excessive manipulation. Drainage took place along the pins and union was obtained in four months. All drainage ceased six weeks after removal of the nails. The author now routinely uses penicillin for a few days after operation and no other closed nailings have been attempted.

All nails were removed for fear that they might become loose and penetrate the ankle joint.

COMPARISON WITH OTHER METHODS OF FIXATION

Intramedullary fixation of the tibia may be briefly compared with other methods of treatment as follows:

1. *Plaster Fixation:* Plaster casts may be entirely adequate for transverse simple fractures and for most fractures in children. Where the fracture is oblique or comminuted, traction must also be applied. This means a greater economic loss in increased hospital stay, loss of time from work, and loss of function of the adjacent joints. Intramedullary pinning provides much better fixation of the fracture, greatly reduces the cost, and maintains function.

2. *Screws:* Screws can be used for oblique fractures but plaster fixation is usually also necessary. Again a considerable amount of function is lost and the patient is not allowed to walk until healing has begun. There is a fairly long period of convalescence.

3. *Lane Plate:* The Lane plate is unphysiological in that it holds the bone ends apart after absorption has taken place, thus slowing down union and not infrequently resulting

in non-union. Slotted plates are preferable to the Lane plates because they allow impaction. However, they must frequently be used with plaster and seldom allow full weight-bearing. There is a risk of loosening of the screws and occasionally of fracture through a screw hole. Exposure is also more extensive than with intramedullary pinning.

4. *External Skeletal Fixation:* Roger Anderson or similar forms of external skeletal fixation by means of pins should not be used in uncomplicated cases. They find their best application in injuries with loss of substance or in extensively comminuted fractures. In these, external skeletal fixation is the method of choice and intramedullary pinning cannot be used.

5. *Rush Pins:* Rush pins are also used for fractures of the tibia. The principle is different from that described in this paper in that three-point fixation is supplied. The author believes that for fractures of the shaft of the tibia, several U-nails give greater fixation, and so allow earlier weight-bearing. On the other hand, for fractures near the end of the bone, particularly those near the proximal end, the Rush pin results in more secure fixation and is preferred. Rush pins also serve well in ankle fractures, but these are beyond the scope of this paper.

To sum up, intramedullary fixation is preferred for fractures of the shaft of the tibia because of more secure fixation, preservation of function, and greatly reduced cost, as it allows short hospitalization and early return to work.

SUMMARY

Thirty-four tibiae have been fixed by means of nested U-nails of which twenty-six have been followed from one to four years. There was rapid union of the tibia in all cases.

Displacement or resection of a piece of the fibula is an essential part of this procedure, in spite of the fact that non-union of the fibula may occur.

External fixation is used only if the fracture is in the proximal third of the tibia.

All patients bore weight on the affected limb within one week of reduction except two with compound comminuted fractures.

Intramedullary fixation is technically more difficult in the tibia than in the femur but otherwise quite as satisfactory.

DISCUSSION

Osteomyelitis in Infants

(*Continued from page 85*)

place for surgery, but we should wait until the infant or child, or the adult, is in condition for the operation and then proceed as promptly as is feasible.

On the other hand, by withholding operation we may be responsible for permanent crippling. I have seen patients treated for weeks with antibiotics while progressive destruction of the bone or joint continued. Equally unfortunate is the withholding of such conservative treatment as may prevent deformities, which develop in addition to the destruction of bone. An antibiotic may attentuate the infection so that the general and perhaps the local symptoms subside, yet because of the presence of granulation tissue in the area and the possibility of an attenuated organism, destruction will continue.

It is true that in many cases there is complete healing with antibiotic treatment, but in others surgery can be very helpful. The operation for drainage is relatively simple and innocuous, but an orthopaedic surgeon is the one who is best qualified to determine when it is indicated.

Dr. Blanche (closing): The discussors have pointed out that these sick babies must receive intensive medical care to save their lives and that early diagnosis must be made of the bone and joint lesion. They also all agree that the purulent joint needs drainage, but do not agree on the means of obtaining this drainage. It seems to me that, if a joint must be drained, it must be drained adequately, and I believe that a surgical incision is much more adequate than is an aspirating needle.

FRACTURES INVOLVING THE DISTAL FEMORAL EPIPHYSEAL CARTILAGE

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From the Sixth Surgical Service, Boston City Hospital, and the Department of Orthopaedic Surgery, Tufts Medical School, Boston

In previous articles by one of the authors[2, 3], as well as elsewhere in the literature, fractures involving the distal femoral epiphyseal cartilaginous plate have been described as fractures of the distal femoral epiphysis. The use of the term "epiphysis" in this connection to designate the epiphyseal cartilage is too indefinite. In the fractures described, the epiphyseal cartilage is involved, the extent of involvement depending on the type of fracture. Only in the rarer vertical fractures of the knee joint is the bony epiphysis actually involved. In the more common avulsion type of fracture, the correct term would be the one we have chosen.

Fractures involving the distal femoral epiphyseal cartilaginous plate are today relatively uncommon injuries. (Only fifteen cases have been seen at the Boston City Hospital in the past five years out of a total of 5,500 fracture cases requiring hospital admission.) Although the literature is rather extensive, most published reports are based upon the experience with one or two patients, few of whom have been followed for more than a few months. Therefore, no clearly defined information on the end results of such injuries can be obtained.

On reviewing the type of surgery performed in most of these cases, one is given the impression that, if growth disturbance with an associated deformity had not followed as a result of the injury, it most certainly should have followed as a result of the surgery. Many of the patients with these fractures were subjected to open reduction with internal fixation either because closed reduction was not obtained or maintained, because the fracture was seen late, or because open reduction was thought by the surgeon to be the method of choice.

The literature is particularly voluminous for the period between the years of 1890 and 1915. The high incidence of such injuries between these years was due to the prevalence of the horse-drawn vehicle. Boys stealing rides on the rear of moving wagons swung their legs from side to side to enable them to get one knee upon the tailboard in order to pull themselves into the wagon. In so doing, a foot frequently became caught between the spokes of a wheel. The epiphysis was thus forcibly avulsed by the traction imparted by the rotatory force of the revolving wheel. The mechanism of the production of such a fracture was one of hyperextension in which the distal epiphysis was displaced anteriorly while the shaft was displaced into the popliteal space. These injuries were extremely serious for many of the fractures were compound and were later complicated by gas-bacillus or tetanus infection, the organisms of which are natural inhabitants of the equine gastrointestinal tract. The greatest danger, however, was caused by the pressure of the displaced shaft on the popliteal vessels and nerves. Hutchinson, in an article published in 1894, described the end results of fifty-eight cases which he had collected from the literature. In twenty-eight patients with clean (closed) fractures, sixteen of the fractures were well reduced and good results were obtained. In twelve, however, reduction was not obtained, and in six of these slough developed which necessitated amputations in four. Of the remaining two patients, one was treated by knee resection and the other by resection of the protruding diaphysis. In thirty patients with open (compound) fractures, there were ten deaths. Of the remaining twenty, seventeen required amputation.

In 1924, Cotton wrote: "The history of such forward displacements is a melancholy

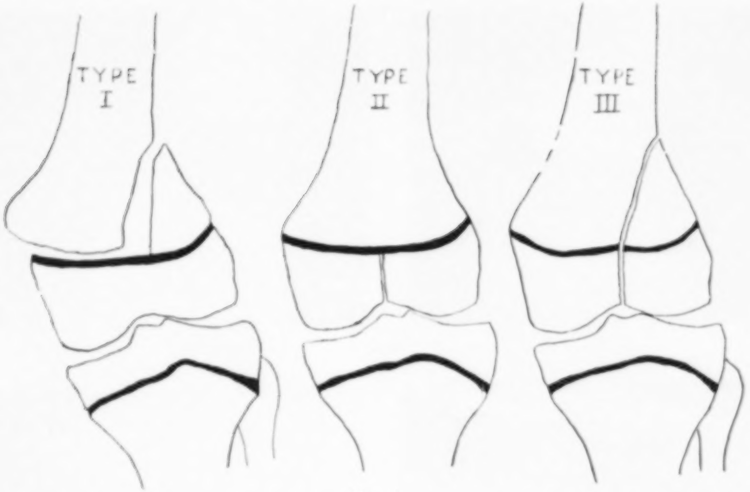

FIG. 1

Diagram to show the three types of fractures involving the epiphyseal cartilaginous plate.

Type I. Avulsion type of fracture due to the pull of the attached ligaments. The entire epiphyseal plate is stripped off the diaphysis similar to stripping up a layer of plywood. The fracture line apparently passes through the zone of degenerating cartilage cells, osteoid tissue, and newly formed bone. Displacement in this type of fracture may be marked, but ultimate deformity due to the displacement or to growth disturbance is rare. The forces of stress and strain (acting according to Wolff's law) ultimately restore the normal shape of the bone, once union of the diaphysis to the epiphysis has occurred. It is to be understood that reasonable apposition at reduction is essential. In cases of complete anterior displacement with the epiphysis lying at right angles to its normal position, nature cannot restore the bone to normal since correcting forces acting upon the epiphysis no longer operate, once the epiphysis has rotated through such a wide arc.

Type II. Compression type of fracture, commonly involving the distal tibial epiphysis but rarely involving the distal femoral epiphysis (Fig. 9). The fracture line may emerge between the bony epiphysis and the epiphyseal plate without damage to the latter; in such a case growth disturbance will not occur. If, however, the fracture line crosses the plate and emerges between it and the diaphysis, then deformity will occur.

Type III. Compression type of injury in which the epiphyseal plate has been crushed between the bony epiphysis and the diaphysis. Deformity is to be anticipated following this type of injury. The fracture line need not be as extensive as that shown in the drawing; it may only involve a small area of bone on either side of the epiphyseal plate or it may be so small as to be overlooked or to be considered as of no clinical or roentgenological significance.

one. There have been many cases of gangrene from vessel damage, and many deaths subsequent to such gangrene. Death or amputation to avert such death seems to be the usual sequel." Cotton then quoted a foreign report, published in 1898, of a series of twenty-two cases in which there were four deaths and fourteen amputations.

Although such serious complications are still occasionally reported, they have become quite rare. None of our patients had open (compound) fractures and none presented either vascular or neurological complications. The horse and wagon as a causative force has been replaced by the football field as a source of this type of injury.

The fifteen patients in the present series have been reviewed: Nine patients have been followed clinically and by roentgenograms from one to eight years. Of these, three patients were examined one year after injury; three patients at two years; and three were examined at four, five, and eight years after injury, respectively. In seven patients, all epiphyses have become fused.

The epiphyseal cartilaginous plate was fractured on the right in four patients, and on the left in eleven.

Type of Fracture

All fractures in this series were of the avulsion type, Type I (Fig. 1), as described in a previous publication[3]. A patient with a fracture illustrative of Type II was recently

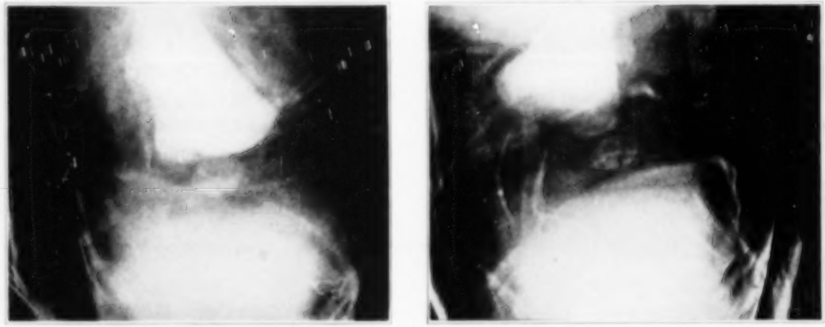

FIG. 2-A

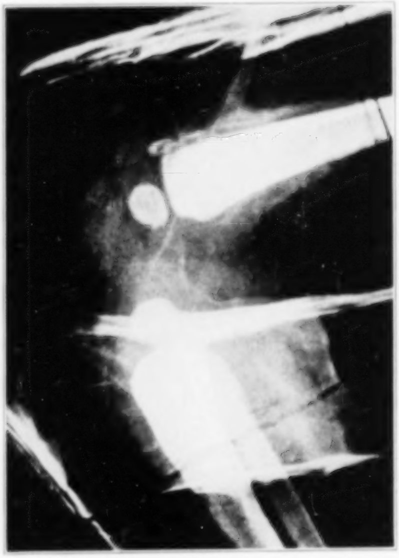

FIG. 2-B

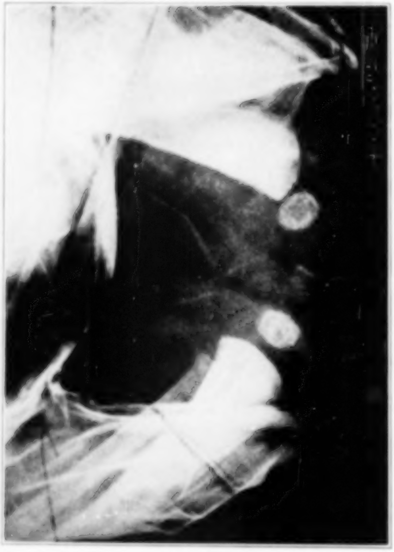

FIG. 2-C

Fig. 2-A: Anteroposterior view of lower portion of the femora of an infant about two weeks following a difficult breech delivery. Both distal femoral epiphyses were laterally displaced. Note callus along lateral margins of the shaft.

Figs. 2-B and 2-C: Lateral views of the distal femoral epiphyses. Note posterior displacement of both epiphyses and the large amount of callus particularly along the posterior aspects of the shaft. A dense mass of bone will eventually develop on the posterior and lateral aspects of the shaft. In this way the shaft is built out to the displaced epiphysis. When bony union has developed, further correction will occur, in conformity to Wolff's law. The zone of degenerating cartilage, osteoid, and preformed bone through which the fracture line readily occurred will become remodeled by the forces of stress and strain.

admitted to the hospital (Fig. 9); this is the only fracture of this type the authors have seen and it is not included in this series. We have never seen a fracture corresponding to Type III, although descriptions of it may be found in textbooks.

Fractures of the avulsion type are by far the most common type of fractures involving the epiphyseal cartilaginous plate, regardless of the epiphysis involved. At open reduction of one fracture of the avulsion type involving the proximal humeral epiphysis and of one compound fracture of the same type involving the distal radial epiphysis, the fracture line was found to extend between the diaphysis and the epiphyseal cartilage. In both instances the cartilage remained attached to the bony epiphysis. We believe

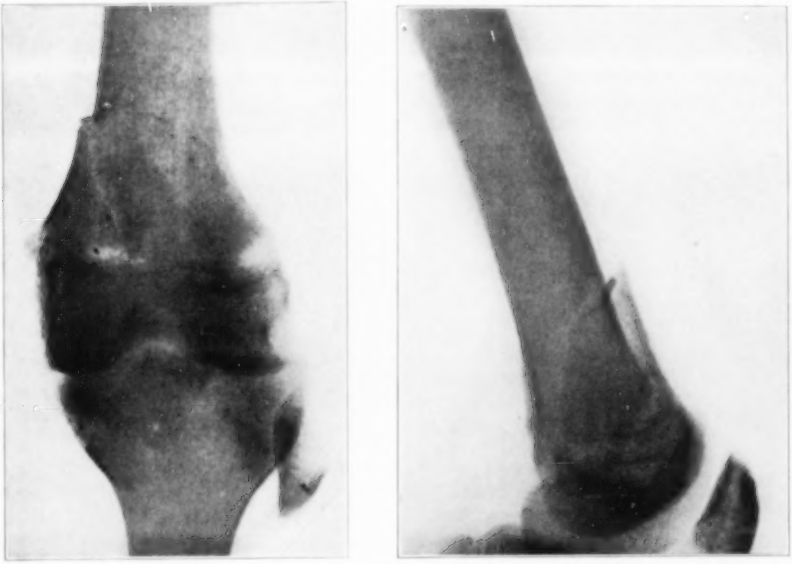

Fig. 3-A

Fig. 3-B

R. K. Anteromedial displacement in a seventeen-year-old boy. Note large fragment from the medial femoral cortex. Further correction was not obtained. Two years later all epiphyseal cartilages became fused. Although there is no deformity, there is shortening of one-eighth of an inch.

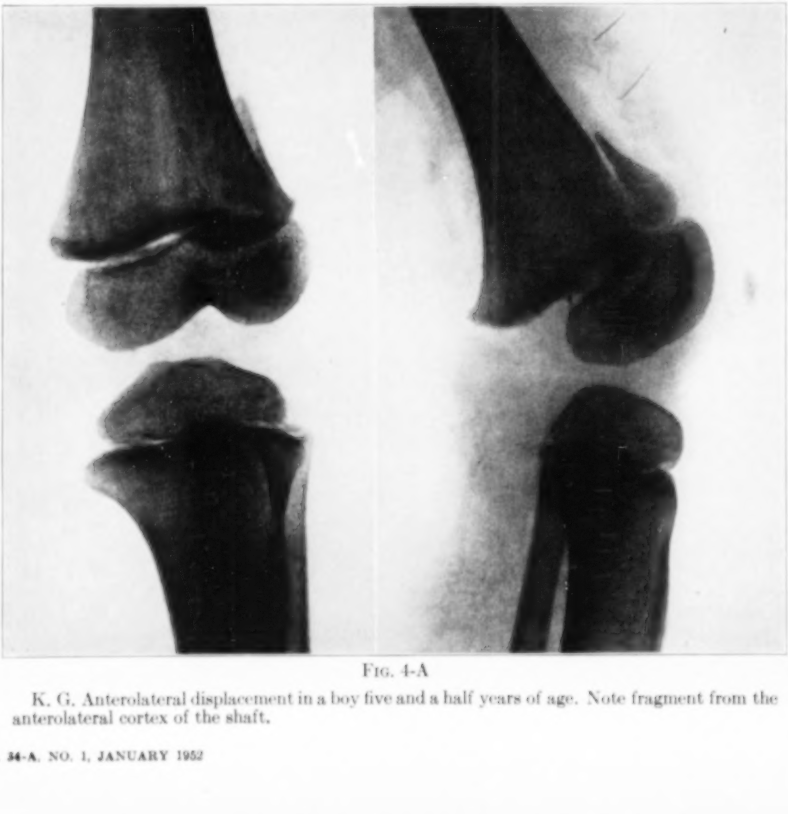

Fig. 4-A

K. G. Anterolateral displacement in a boy five and a half years of age. Note fragment from the anterolateral cortex of the shaft.

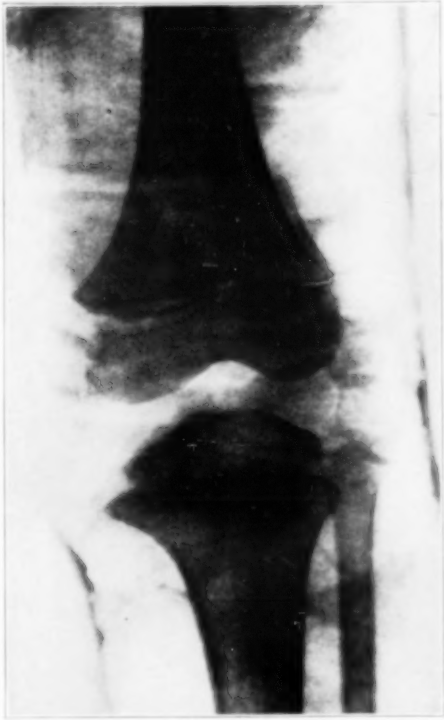

Fig. 4-B

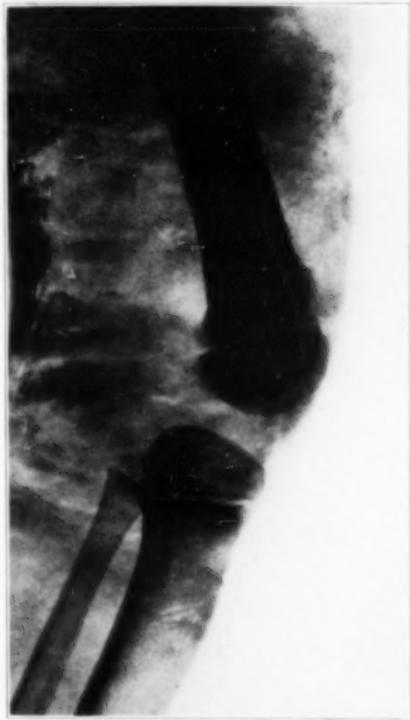

Fig. 4-C

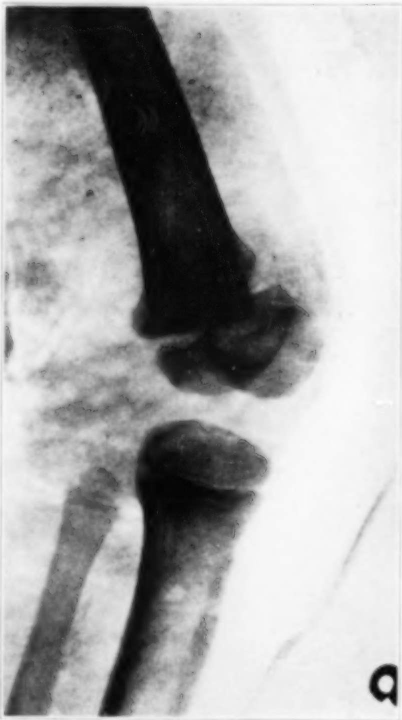

Fig. 4-D

Figs. 4-B and 4-C: Anteroposterior and lateral views showed satisfactory reduction. There was insufficient flexion to insure maintenance of position.

Fig. 4-D: Lateral view showed recurrence of deformity during immobilization. Had the leg been immobilized in flexion of between 60 and 90 degrees, the original position would have been maintained. This patient was lost to follow-up.

that fractures involving the distal femoral epiphyseal cartilaginous plate are analogous and that the fracture line runs through the weakest point of the epiphyseal-diaphyseal juncture. This is the region in which the degenerating cartilaginous matrix is invaded by blood vessels from the diaphysis and is replaced by osteoid tissue and immature bone. The all-important epiphyseal plate, from which all future growth will occur, is, therefore, not directly involved. Serious growth disturbance with shortening may occur, but deformity is unusual even in those patients in whom anatomical reduction has not been maintained.

Age at Time of Injury

Most authors state that the distal femoral epiphyseal cartilage does not become fused until the twentieth year. It has been our experience that fusion occurs by the eighteenth year.

We have seen roentgenograms of one patient who suffered bilateral fracture involving the femoral epiphyses with posterolateral displacement, following breech delivery (Figs. 2-A, 2-B, and 2-C). We have not, however, been able to follow this patient and the child is not included in this series. A patient with unilateral fracture involving the femoral

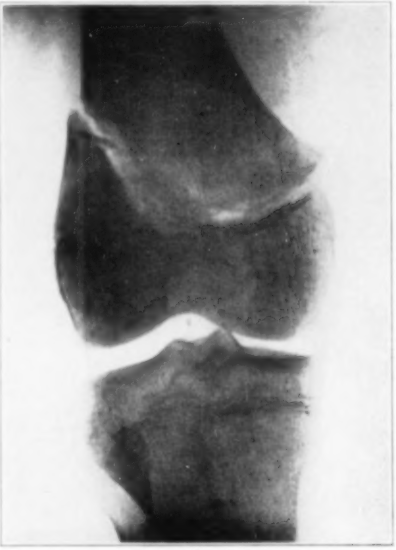

Fig. 5

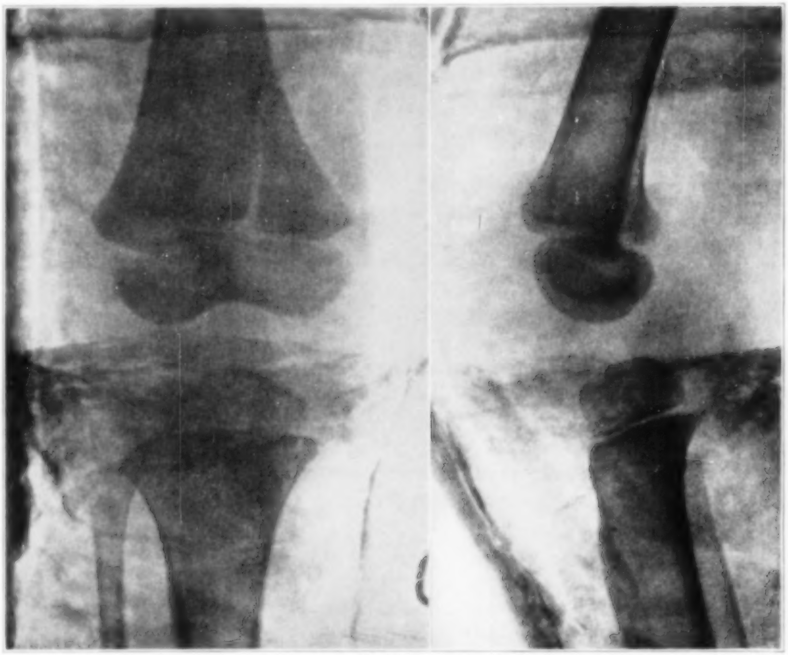

Fig. 6-A

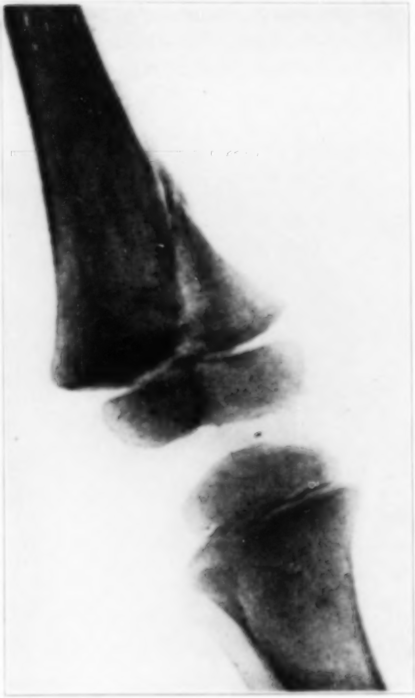

FIG. 6-B

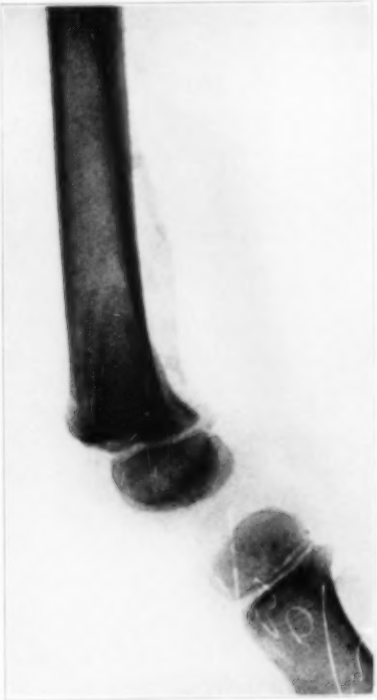

FIG. 6-C

Fig. 5: H. W. Lateral displacement in anteroposterior view. There was no evidence of displacement in the lateral view; however, the position was not improved. Patient was sixteen years of age at the time of injury. Epiphyseal cartilages have now become fused. There is no deformity, but there is shortening of three-eighths of an inch.

Fig. 6-A: F. W. Posteromedial displacement in a three-year-old boy struck by an automobile. Note fracture of the posteromedial aspect of the diaphysis.

Figs. 6-B and 6-C: Anteroposterior and lateral views on removal of cast. The displacement has persisted. This case was lost to follow-up.

epiphysis with posterior and lateral displacement following breech delivery has been reported by Burman and Langsam. In their review of the literature of such obstetrical fractures, they quote three cases of posterior displacement described by Poland, a unilateral case described by E. D. Truesdell, and several bilateral cases described by R. Massart and B. Pincherle. Similar cases have been reported in the European and South American literature.

In the largest group in our series, ten patients, the fractures occurred between the ages of thirteen and seventeen years. All of these patients were seen between the months of September and December and all of the fractures were caused by accidents sustained on the football field.

In the second largest group, four patients, the fractures occurred between the ages of three and five years. These fractures were due either to automobile accidents or to falls from a height.

Type of Injury

The injury was usually received while the boy was running and was generally the result of being tackled. While the body weight was upon one foot with the knee either in extension or, more often, in flexion, the weight of the opposing player's body was directed

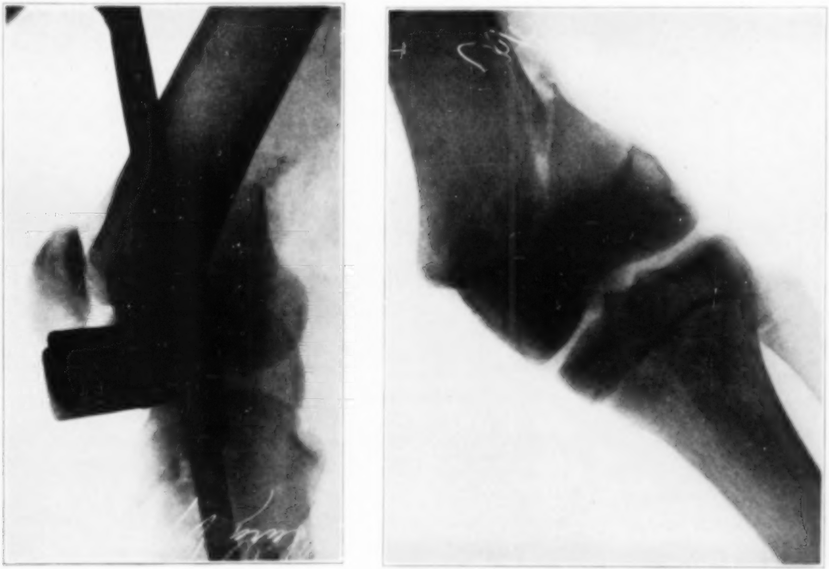

Fig. 7-A

Fig. 7-B

F. McW. Posterolateral displacement in a fifteen-year-old boy. Note that the femoral condyles are not flexed on the tibia but are actually extended. The attachment of the medial head of the gastrocnemius to the shaft has prevented flexion. This fracture could, however, have been reduced and maintained in extension. Despite open reduction, the epiphyseal cartilages have become fused without deformity or shortening.

against the leg. The knee was thus forced either into a bow-leg or a knock-knee position, throwing great strain upon either the tibial collateral ligament or the fibular collateral ligament which, in turn, exerted tension upon its attachment to the femoral condyles, causing these structures to become avulsed from the shaft. Displacement of the epiphysis may be marked and may occur in any direction. Although most publications describe the classical anterior displacement due to hyperextension, there was but one patient with a fracture of the classical type in our series. There were, however, two other patients having anterior displacement. In one, the displacement was medial with a fragment from the anteromedial femoral shaft (Figs. 3-A and 3-B). In the other, the displacement was anterolateral with a fragment from the anterolateral cortex of the shaft (Figs. 4-A through 4-D).

In four patients, the displacement was lateral. In all of these, there was an associated fracture of the lateral femoral cortex (Fig. 5).

There were two patients with posteromedial displacement associated with fracture of the posteromedial femoral cortex (Figs. 6-A, 6-B, and 6-C).

In three patients the displacement was posterolateral associated with fracture of the posterolateral cortex (Figs. 7-A and 7-B; 8-A through 8-D).

TREATMENT

Fourteen patients were treated by manipulation under anaesthesia and by immobilization in either a single leg spica or a toe-to-groin cast. In patients with anterior displacement the leg was immobilized in flexion; in others the leg was immobilized either in full extension or in a few degrees of flexion at the knee. We believe the angle at which the knee is immobilized to be of great importance. In the nine patients whom we have followed, anatomical reduction was maintained in only two. Recurrence in patients with anterior displacement was the result of the immobilization of the leg in insufficient flexion.

TABLE I

Case	Age at Injury	No. of Years Follow-up	Present Status of Involved Epiphysis	Status of Opposite and Tibial Epiphyses	Deformity	Shortening (*Inches*)
1. K.	17	2	Fused	Fused	0	1/8
2. W.	16	2	Fused	Fused	0	3/8
3. D.	17	4	Fused	Fused	0	0
4. M.	4½	5	Open	Open	0	0
5. B.	8	8	Fused	Fused	0	0
6. D.	15	1	Fused	Fused	0	0
7. R.	13	1	Fused	Open	0	5/8
8. P.	16	1	Fused	Fused	0	0
9. McW.	15	2	Fused	Fused	0	0

This is well demonstrated in Figure 4. In this patient, recurrence developed in plaster. If the knee had been immobilized in flexion of 60 to 90 degrees, such redisplacement could have been prevented.

In patients with complete anterior displacement, a position of acute flexion, recommended by Hutchinson and Cotton, may be necessary. If this position is used, the knee should be gradually extended, according to the method of Griswold, or considerable difficulty may be experienced in regaining extension. In patients in whom anterior displacement is incomplete, the immobilization in acute flexion is unnecessary. Immobilization in flexion of not less than 60 degrees seems to be the safest position for at least the first few days. Thereafter the cast may be wedged and the knee may be brought into gradual extension. The authors do not agree with Patterson that these patients, after reduction in flexion, can be safely treated in extension.

Failure to maintain position in patients with posterior displacement was usually the result of immobilization in partial flexion rather than in extension. In the only patient in our series for whom traction was applied, the knee was kept in a position of semiflexion (Figs. 7-A and 7-B). At no time was reduction obtained. Eventually open reduction followed by quadricepsplasty was necessary to restore position and function. This is the only poor result in the series; it is probable that this could have been avoided by immobilization in full extension following the manner of treatment demonstrated in Figures 8-A through 8-D. The authors believe that patients with posterolateral displacement are likely to be treated by immobilization in flexion. This treatment is based upon the well-known fact that fractures in the supracondylar region require a position of flexion to relax the pull of the gastrocnemius muscle. In this fracture, however, the fracture line occurs above the attachment of the gastrocnemius; consequently, the unopposed pull of the muscle causes a posterior displacement of the condyles in relation to the shaft, and also flexion of the condyles in relation to the tibia. In fractures through the epiphyseal cartilaginous plate, the fracture line passes distal to the medial head of the gastrocnemius as the head of this muscle takes its origin from the shaft above the epiphyseal plate. Consequently, in fractures through the epiphyseal cartilage, although there may be posterior displacement, flexion of the epiphysis on the tibia does not occur. The position of flexion in immobilization is contra-indicated, for the relaxation of the gastrocnemius enhances posterior displacement. With the joint immobilized in a position of extension, the taut medial head acts as a posterior splint and tends to prevent posterior displacement.

Lateral displacement can usually be maintained if the leg is immobilized in extension with the knee in a varus position. Plaster immobilization for the patients in this series was maintained from four to eight weeks.

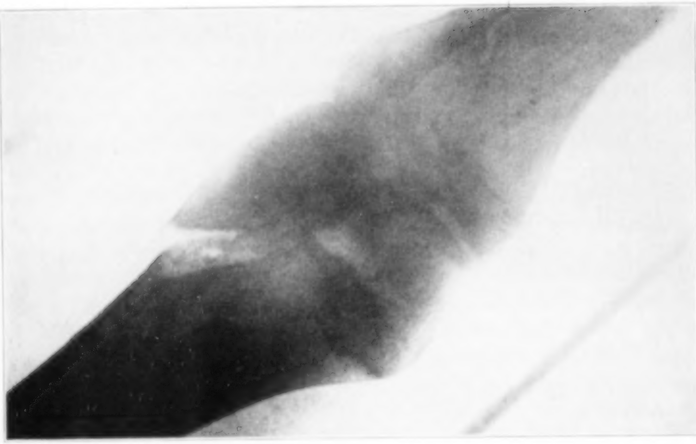

FIG. 8-A

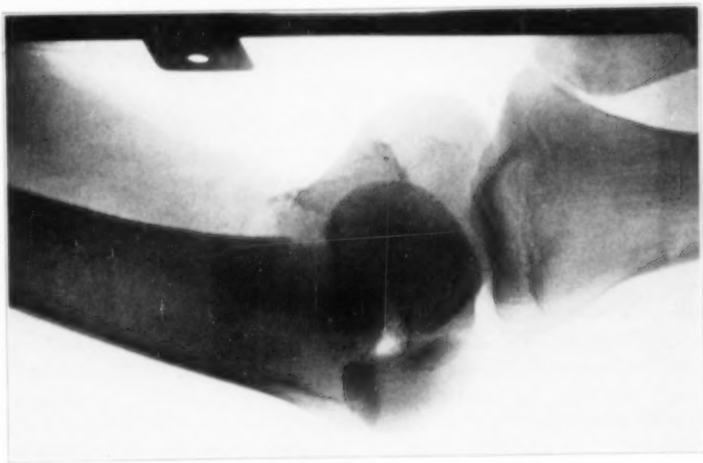

FIG. 8-B

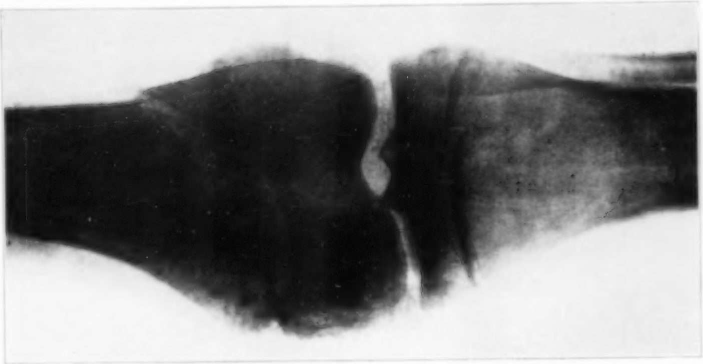

FIG. 8-C

Figs. 8-A and 8-B: W. D. Posterolateral displacement of the distal femoral epiphysis in a fifteen-year-old boy. Note that the femoral condyles are actually extended on the tibia and are not flexed as would be the case in a supracondylar fracture.

Figs. 8-C and 8-D: Note excellent position obtained by immobilization in extension. The epiphyseal cartilaginous plates about the knee became fused one year after the injury without deformity or shortening.

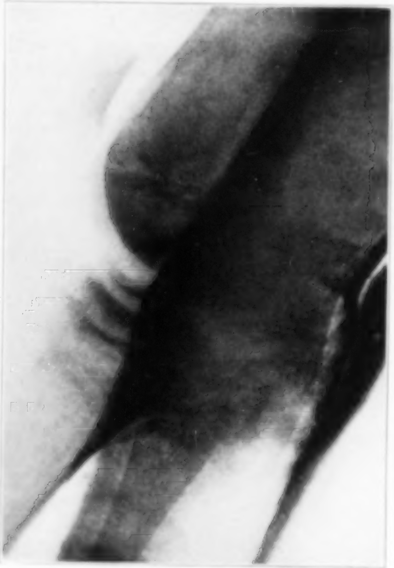

FIG. 8-D

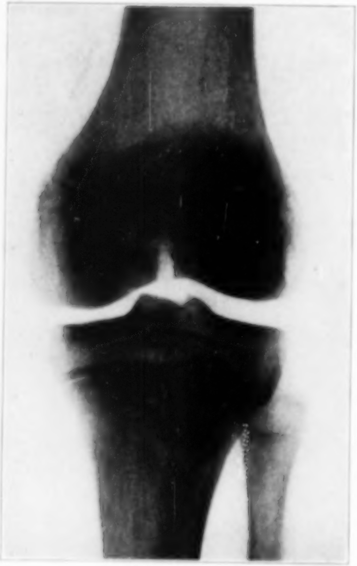

FIG. 9

Fig. 9: Fracture, Type II, in a fifteen-year-old boy. The lateral condyle is displaced slightly outward. Whether the epiphyseal plate has been fractured or crushed cannot be determined by x-ray. A guarded prognosis must therefore be given. In all probability deformity will follow this fracture unless the entire epiphyseal cartilaginous plate undergoes ossification.

RESULTS

In seven of the nine patients, fusion of all epiphyseal cartilages about the knee has occurred bilaterally; in two patients, one year after the injury; in three patients, two years; in one patient, four years; and in one, eight years after the injury. In none of these patients is there any deformity. In one patient, a seventeen-year-old boy, a transdiaphyseal osteotomy was performed six months after the injury because of persistent lateral displacement. Despite the fact that the procedure failed to correct the deformity, no clinical or roentgenographic evidence of deformity is present four years after injury. In two patients, there is slight shortening. In one patient, seventeen years of age, with anteromedial displacement (Fig. 3-A), there is shortening of one-eighth of an inch. This patient was injured two years ago. All the epiphyseal cartilages are now fused. In a second patient, a sixteen-year-old boy with lateral displacement, there is shortening of three-eighths of an inch. The injury occurred two years ago and all epiphyseal cartilages are now fused. Whether the slight shortening in these patients was due to premature ossification or retardation of growth cannot be determined as ossification had occurred by the time of re-examination.

In two patients the epiphyseal cartilages have not yet closed. In one patient, four and one-half years of age at the time of injury, who was examined five years later, there was no deformity and no shortening. To all appearances the epiphyseal cartilages are normal.

In the second patient, a thirteen-year-old boy injured one year ago, there was originally only slight lateral displacement. Anatomical reduction was obtained and maintained. One year later there was shortening of five-eighths of an inch. The femoral epiphyseal cartilage of the affected side is fused, but it is open in the normal femur, indicating that further shortening will probably occur as further growth of the normal femur may continue for another three years.

In a previous series of patients followed some years ago, two cases anatomically reduced showed eventual shortening of one inch and three inches, respectively. It would thus appear that some degree of shortening due either to premature ossification or retardation of growth occurs quite frequently following fractures involving the distal femoral epiphyseal cartilaginous plate. In most instances this is of no clinical significance, but it may on occasion assume major proportions. The degree of eventual shortening in fractures of this type involving other epiphyses apparently bears no relation to the amount of original displacement. Although the fractures described have all been of the avulsion type in which the epiphyseal cartilaginous plate itself is theoretically undamaged, some damage does occur in a small number of cases. This is to be explained by the fact that this epiphyseal cartilaginous plate is the largest in the body and considerable force is required to cause displacement. As this is the most actively growing of the epiphyses, any damage to the plate causing retardation of growth is more apt to be noticed. It is to be pointed out that retardation of growth is not associated with deformity. This indicates that such damage must be uniformly distributed throughout the epiphyseal plate.

We have seen no cases of deformity such as those reported by Siegling or by Abbott and Gill. In the case reported by Siegling there was apparently no definite evidence that the epiphyseal cartilaginous plate had actually been involved in the fracture. In only two of the five cases reported by Abbott and Gill could the deformity be attributed to fracture. Unfortunately the original roentgenograms were not reproduced by these authors.

Although we have seen overgrowth as the result of fracture involving the distal radial epiphyseal cartilage, no such phenomenon was noted in this series. Bellin, however, reported a patient in whom overgrowth of one inch developed which was associated with a slight knock-knee deformity four years after the original injury.

Knee Motion

Four patients suffered some loss of knee flexion. In one patient such loss amounted to 10 degrees. In three patients the loss was from 15 to 20 degrees. In three patients there was 5 to 10 degrees of hyperextension of the affected knee. In two of these, there was an associated loss of 10 to 20 degrees of flexion.

In four patients, there was some evidence of relaxation of the anterior cruciate ligament. The original displacement had been lateral in three and posterolateral in one. The mechanism of the apparent injury to the anterior cruciate ligament is not understood.

SUMMARY AND CONCLUSIONS

Fractures involving the distal femoral epiphyseal cartilaginous plate are uncommon injuries. Fifteen cases have been seen at the Boston City Hospital in the past five years out of a total of 5,500 fracture admissions.

Nine patients have been followed from one to eight years. In seven cases all epiphyseal cartilages are now fused. All fractures were of the avulsion type. Displacement occurred in any direction.

Most fractures occurred in males between the ages of thirteen and seventeen years. In the older age group all fractures were the result of football accidents, and all were seen in the autumn months.

In only two cases was anatomical position maintained. Attention is called to the role played by the medial head of the gastrocnemius in fractures with posterolateral displacement. Such fractures must be immobilized with the joint in extension in contradistinction to supracondylar fractures which appear to be similar but require immobilization of the joint in flexion for the maintenance of reduction.

Deformity did not develop in any patient.

Shortening due either to premature ossification or retardation of growth or both is not uncommon but only on occasion is it of clinical significance. In this series, shortening occurred in three patients; in only one, however, was it of potential clinical importance.

The knee joint showed slight loss of flexion in four patients; slight hyperextension was present in three patients; and an unexplained relaxation of the anterior cruciate ligament occurred in four patients.

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REDUCTION OF ANTERIOR DISLOCATIONS OF THE SHOULDER BY MEANS OF THE MILCH ABDUCTION TECHNIQUE

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From the Division of Orthopaedic Surgery, Department of Surgery, University of Rochester School of Medicine and Dentistry, Rochester

The method of reducing an anterior dislocation of the shoulder by means of the abduction technique described by Milch[1] is an anatomically reasonable and safe procedure which obviates the routine use or even the occasional use of anaesthesia.

Eighteen reductions have been done by the authors by the use of this abduction technique; the last twelve of these reductions were performed with the patient in a prone position. We have found the technique much easier to use when the patient is in a prone position, for the patient is more relaxed and the surgeon has greater control of the arm. There seems also to be a distinct advantage in the initial deliberate flexing of the elbow to 90 degrees. This relaxes the grip of the long head of the biceps which tends to maintain the dislocation.

None of the eighteen patients required an anaesthetic. The gentleness of the technique is further emphasized by the comfort of even the most anxious patients during the unhurried execution of the manoeuvre.

The drawings illustrate the technique of reduction. With the patient prone, pillows are placed under the pectoral muscles of the involved side; the arm is allowed to swing freely (Fig. 1). The patient is assured that no sudden forcible movements will be carried out. Spontaneous reduction from relaxation upon assuming the prone position is fairly common. If reduction does not occur spontaneously, the elbow is flexed to 90 degrees. This removes the short-circuiting action of the long head of the biceps and reduction may occur at this stage.

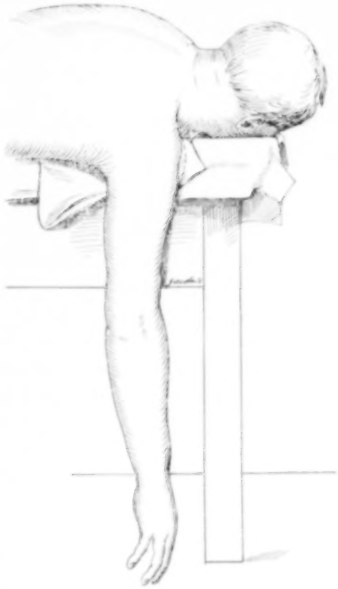

FIG. 1

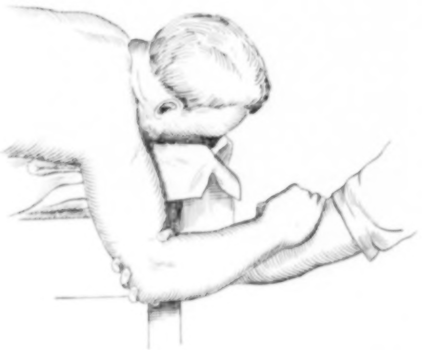

FIG. 2

The hand of the involved arm is then placed over the supinator mass of the corresponding arm of the surgeon whose fingers and thumb can then grasp the elbow firmly (Fig. 2), while he initiates and controls gentle longitudinal traction, abduction, and external rotation (Fig. 3). With his contralateral hand held about the upper portion of the patient's humerus, the surgeon increases the gentle abduction and external rotation. If reduction has not occurred by this time, he gives a final "lift" over the glenoid.

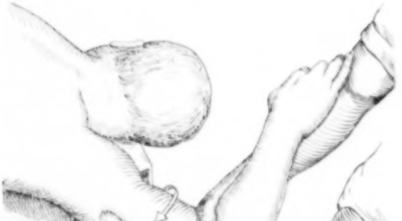

FIG. 3

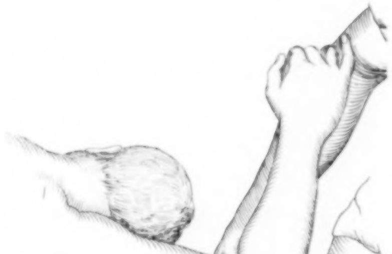

FIG. 4

It is important that the surgeon be willing to take as long as is necessary to keep from hurting the patient in performing the abduction. He should be careful to stay below the level of pain, for pain causes spasm. There is no place for force in this procedure.

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THE SENESCENT HUMAN VERTEBRA

CONTRIBUTION TO HUMAN OSTEOGENY. III *

BY EDGAR M. BICK, M.D., AND JOSEPH W. COPEL, M.D., NEW YORK, N. Y.†

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It is generally conceded that the biological process of aging begins at the instant of maturity and continues insidiously thereafter. The process has been variously defined, but may be characterized as that period in the life of an organism when the rate of cellular proliferation declines steadily as compared with the rate of destruction. The question of what constitutes senescence in its broader sense has a literature of its own [7,8,9], and the same is true of the problem of its cellular or biochemical origin [1,7,9]. Neither of these subjects will be discussed here. Whatever the origin of the process, its importance to the organism lies in its effect on the structure or function of constituent tissues. Therefore, any consideration of senescence in the vertebra would be well served by a serial demonstration of the histological process in human specimens. This has not to our knowledge been presented heretofore.

Modern osteology stresses the concept that cytological and biochemical reactions are important only in so far as they construct or destroy the basic material of bone substance, since the primary purpose of the skeleton is to provide support. This basic material, as in all other tissues of mesenchymal origin, is extracellular. In bone it is the protein-collagen complex of the trabeculae, the structural product of the process of ossification within which, by some chemical reaction not yet fully understood, bone salts are deposited.

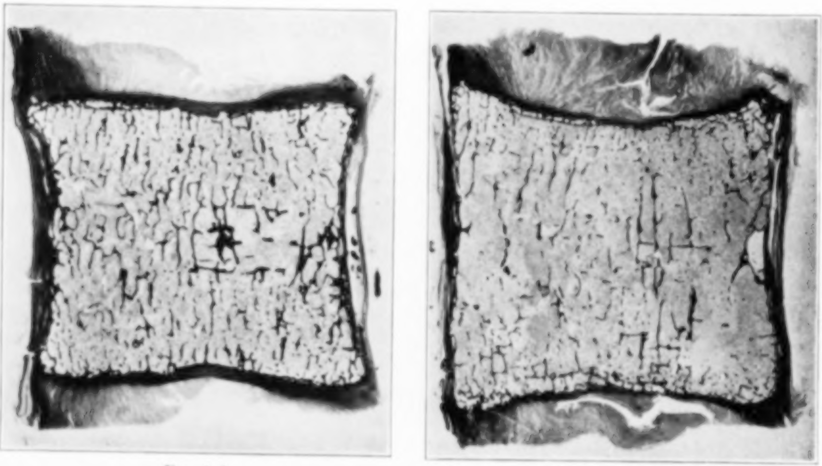

FIG. 1-A

FIG. 1-B

Fig. 1-A: Section of vertebra from male, thirty-six years old.

Fig. 1-B: Section of vertebra from male, eighty-six years old, stained by van Gieson technique to demonstrate fundamental characteristic of senescence, the failure of collagen replacement. The preponderence of longitudinal residual trabeculae is evident in the sections.

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* Read at the Annual Meeting of The American Orthopaedic Association, White Sulphur Springs, West Virginia, June 23, 1951.

† With the technical assistance of Mrs. Sarah Spector.

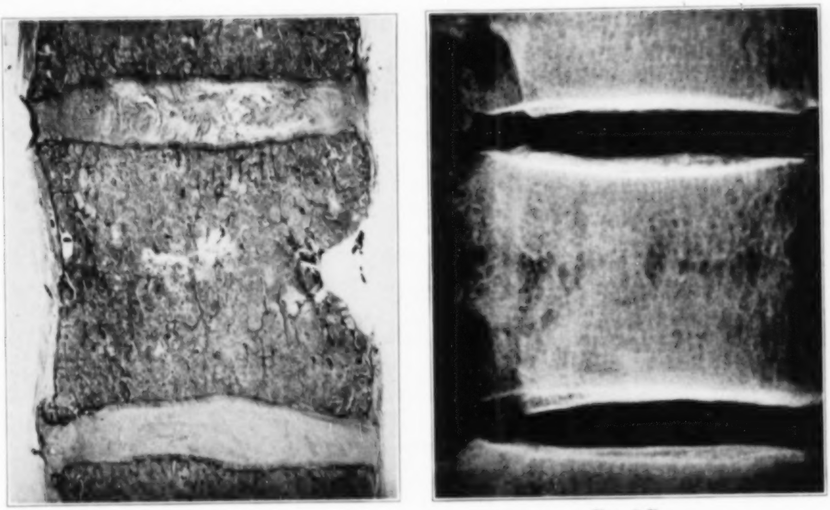

Fig. 2-A

Fig. 2-B

Sagittal section from male, sixty-two years old, hematoxylin-eosin stained, and corresponding roentgenogram. Note thin and relatively sparse trabeculae, decrease in cellularity, and areas of avascular necrosis or infarct corresponding to lytic areas in the roentgenogram.

The fundamental characteristic of senescence in bone is the progressive failure of the osteoblastic mechanism to continue to supply the characteristic extracellular substance of the trabeculae, while the normal absorptive process continues or possibly accelerates. One may call this inverted reaction the natural process of de-ossification. It must be

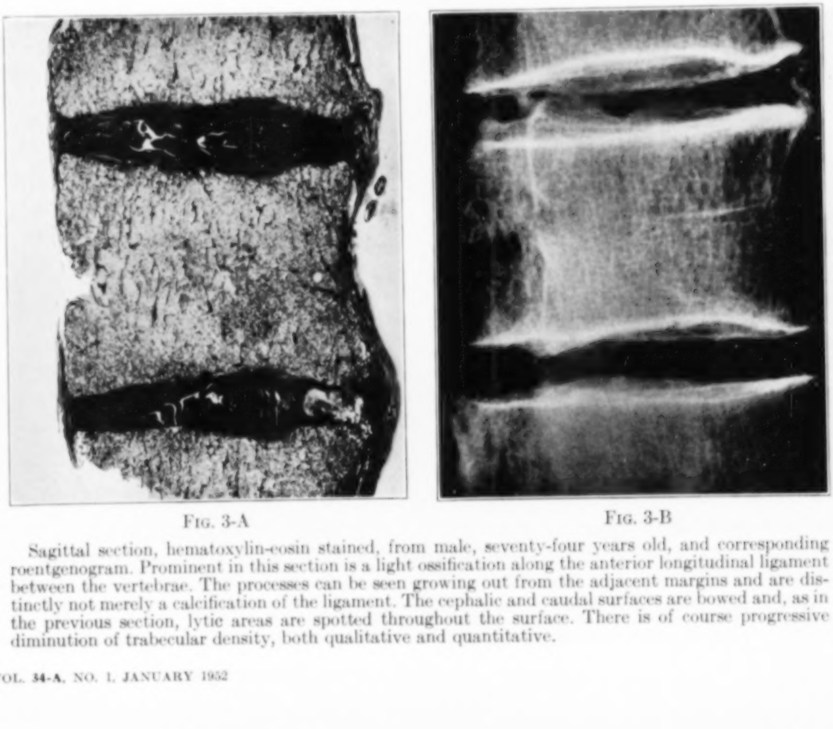

Fig. 3-A

Fig. 3-B

Sagittal section, hematoxylin-eosin stained, from male, seventy-four years old, and corresponding roentgenogram. Prominent in this section is a light ossification along the anterior longitudinal ligament between the vertebrae. The processes can be seen growing out from the adjacent margins and are distinctly not merely a calcification of the ligament. The cephalic and caudal surfaces are bowed and, as in the previous section, lytic areas are spotted throughout the surface. There is of course progressive diminution of trabecular density, both qualitative and quantitative.

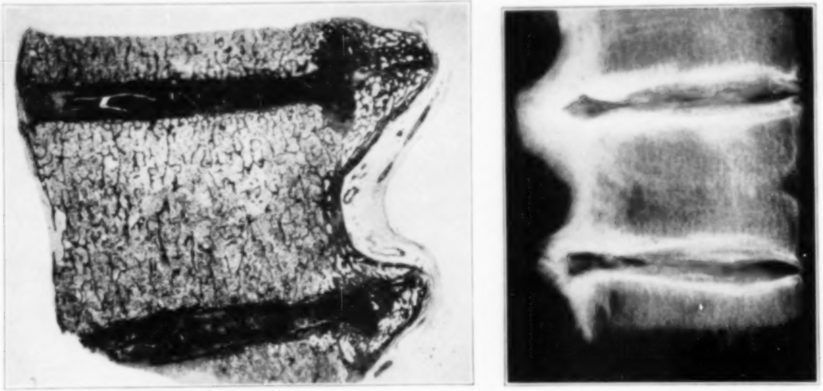

FIG. 4-A FIG. 4-B

Section of vertebra from male, seventy-two years old. The specimen and corresponding roentgenogram are a fine example of the osteohistology of a fully developed ossified "bridge" at both ends of a vertebra. The failure of formation of trabeculae in the body is not as marked as in the previous specimen (it is from a person two years younger), but areas of infarct are equally numerous.

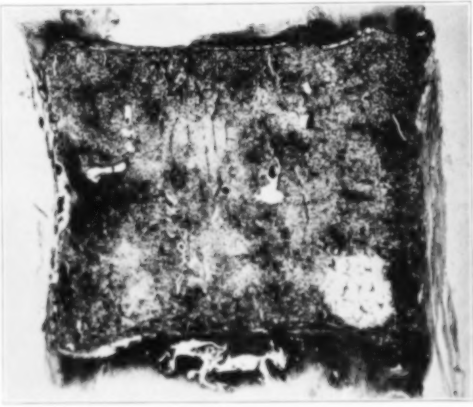

FIG. 5

This section from a male, eighty-five years old, illustrates an advanced degree of multiple localized infarction, with remarkably little change in the contour of the vertebral body. The trabeculae are thin; the dense cellularity in this specimen is composed chiefly of red blood cells extravasated into the narrow spaces.

emphasized that this process is not one of decalcification. The trabecular substance which remains at any stage of senescence is ordinarily well calcified.

Two other histological reactions found within the senescent vertebra are local responses to factors which begin to operate outside its boundaries. One is found only at the periphery of the cephalic and caudal surfaces. This is an osseous response to the wear-and-tear degeneration of articular cartilage and takes the form of osteophytic protuberances. Articular degeneration ordinarily appears at a much earlier age than the histological signs of senescence within the vertebra, and the peripheral reaction to it may therefore also be expected to precede the changes within the vertebra. Hence, while peripheral osteophytosis may accompany the process of senescence, it is not directly a part of it. The second reaction appearing in the specimens is that of isolated patches of avascular necrosis without replacement. In none of our specimens were these areas extensive enough to cause collapse of the surrounding bone. This type of necrosis is common to all aging tissues and probably reflects the process of senescence in the circulatory apparatus.

It is necessary in a project such as this to make certain arbitrary decisions in the choice of material. Our specimens consisted of sagittal sections of vertebral bodies removed from fresh cadavera presenting no perceptible disease of the locomotor apparatus. All were over sixty years of age. This age limit was chosen because our observations have taught us that the histological changes in senescence, as distinct perhaps from the metabolic or cellular changes, generally become visible at about sixty years. The sections illustrated herein were chosen from a series of twenty-five, and each chiefly demonstrates one particular characteristic.

Figures 1-A and 1-B graphically demonstrate the fundamental defect of senescent bone. Both were stained by van Gieson's method in order to accentuate the diminution of trabeculae in the collagen, the process we call de-ossification. Figure 1-A is that of a mature specimen (age thirty-six); Figure 1-B is that of a male eighty-six years old. The difference in trabecular density and quantity is obvious. The greater quantity of residual trabeculae set in the vertical or anti-gravity plane, as compared to lateral or oblique, confirms previous observations on the effect of function even on the process of senescence [9].

SUMMARY

The process of senescence in the human vertebra uncomplicated by pathological endocrine disturbances is characterized by three histological reactions. Only one of these is directly physiological; the other two are the products of extraneous influence.

The fundamental characteristic is loss of trabecular substance due to the failure of formation of collagen while its normal, or possibly accelerated, absorption continues.

A second manifestation, which may start many years earlier and is often but not necessarily present, is that of osteophytosis about the periphery of the cephalic and caudal margins of the vertebral body. This is particularly prominent along the line of the anterior longitudinal ligament. It is a proliferative reaction of subchondral bone to the wear and tear of the articulating cartilaginous surfaces.

The third histological characteristic is to some extent always apparent. One or more small areas of localized avascular necrosis or infarct spread through the spongiosa. These may be quite numerous in aged specimens, but have not been seen to coalesce and therefore do not apparently become large enough to cause gross collapse of the vertebrae.

DISCUSSION

As in our previous publications [4,5] on the osteohistology of the human vertebra in its various stages of development, we have been content merely to report our observations and interpret their histological significance. The implications of these observations as regards a large variety of clinical subjects are properly matters for separate consideration.

We have already discussed the relationship of senescent changes to vertebral fractures [3]; in fact, that study led to the present investigation.

The broader subject of chronic backache in the aged certainly belongs to a category different from that of backache in youth or maturity. Our observations may help to clarify some of these syndromes. It is evident that the appearance of osteophytosis in an aged spine cannot be passed off simply as arthritis, nor can the appearance of a usual degree of spotty lysis in a senescent vertebra be classified as pathological osteoporosis.

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DISCUSSION

Dr. Arthur Steindler, Iowa City, Iowa: One point that Dr. Bick has brought out in his interesting paper is that atrophy, the essential characteristic of senescent vertebrae, is a result of tissue exhaustion rather than the response to a pathological endocrine or vitamin deficiency. As Pommer has pointed out, the essence of bone atrophy is that the normal loss of bone by lacunar absorption is only inadequately met by bone apposition. That is to say, it is the decrease in bone apposition and not the increase in bone resorption which overthrows the balance.

As regards the appearance of perpendicular striations in the aged vertebra mentioned by Dr. Bick, we must realize that it is due entirely to the atrophy of secondary oblique or traction systems of trabeculation. This is a general physiological law which applies to all forms of atrophy. F. Muller observes that in case of atrophy those trajectory bone systems which are of greater static importance either retain their normal amount of calcium or even draw calcium material from such trabecular systems as are of lesser importance. In this connection we note nature's attempt to restrict the rotatory range between the vertebrae by calcification of the ligamentous apparatus; it is the progressive degeneration of the disc which imposes such restriction. This is in accord with the necessity of preserving the most important pressure systems of trajectories at the expense of the lesser trajectory systems subserving pull and traction.

Likewise it should be remembered that, aside from mechanical factors of external stresses, there is also a rapid decline in the circulatory supply of bone in old age. The argument against the theory of deficient bone apposition, that fractures heal in the old as well as in the young, does not seem valid any more than it is regarding the capacity of bone to regenerate in younger persons with fragilitas ossium or with hunger osteopsathyrosis; these fractures are episodic events and do not represent a permanent pathological situation. The force of repair is of such potency that it commandeers calcium supply elsewhere to bring about physiological repair. No one can deny the general atrophy in hunger osteopsathyrosis nor the acute local atrophy and calcium withdrawal at the site of a fracture.

Perhaps the point of greatest interest brought out by Dr. Bick is the question of molecular aseptic necrosis as a part of senile osteoporosis of the spinal column. The fact that osteocytes disappear, leaving empty lacunae, has not, so far as I know, been mentioned in the literature. I wonder if these areas of necrosis could not be due to infractions of the vertebrae similar to the process we see in Kümmell's kyphosis.

As Dr. Bick has said, the essential feature is the impotence of osteoblastic activity, and he adds that, in anticipation of this fact, nature has the foresight of restricting motion to minimize functional stresses, preserving as it were the weight-bearing trabecular system at the expense of other secondary trajectories. She does this by formation of bone bridges and by calcification further necessitated by the progressive degeneration of the disc.

All these are signs of involutional adaptation rather than of true morbidity. It is difficult, in fact, to draw a line between pathological and constitutional changes, between true avitaminosis and endocrine deficiency on the one hand and senile osteoporosis on the other. A degree of avitaminosis is normal in the aged. For instance, the ascorbic-acid level may be as low as 0.2 to 0.3 milligram per 100 cubic centimeters as against 0.7 in the normal adult; there is an increase in lipoids; there is a natural dysfunction of the endocrine glands; the absorption in the intestinal canal is deficient; hypocalcaemia and hypophosphataemia, due to hepatic and pancreatic deficiency, are found. It would seem, then, that the histological make-up of the senescent vertebral column merely reflects a series of deficiencies peculiar to old age.

But what constitutes old age? Dr. Bick has pointed out that the biological course of aging starts at the instant of maturity. Only under this condition may we accept the definition of senescence. We must keep well in mind the fact that signs of senescent exhaustion may be present in the human spine at the time when other systems of the body are still at the height of their function; yet the skeletal system of an octogenarian may be in better condition than that of another man of fifty. There is no strict chronological timetable for senescence, not even for the skeletal system. The response of the human body to wear and tear depends on many other factors besides the passage of time.

This has been a most interesting paper and I appreciate the privilege of being asked to discuss it.

ORTHOGRAMS OF POSTURE *

BY CHARLES WEER GOFF, M.D., HARTFORD, CONNECTICUT

Ever since the publication of Goldthwait's classic monograph on body mechanics, the orthograde posture of man has been typified by a lateral view or profile, taken with the subject standing erect and at ease. Almost as many authors have reported their studies of the posture of school children and of university freshmen, using this system, as there have been individuals studied. Man's posture has been a subject of intense interest to anthropologists and particularly to orthopaedic surgeons who are properly concerned with body mechanics. The bent knee stance has long been associated with primitive man, rightly or wrongly, while military carriage has been idealized.

In a field replete with literature of all sorts, it is possible to select a few works which may serve to summarize the whole.

Schwartz devised a lumbosacral index of posture and quoted Cunningham as believing that Europeans represented a higher "race" of man because they were reported to have the greatest lumbosacral curve. Plumb lines have been dropped and posture angles have been constructed by Akerblom and numerous others. Howorth emphasized dynamic posture; and the report of the Posture Committee of The American Academy of Orthopaedic Surgeons presented a modest but rational approach, which introduced, however, no new material.

The same error which has been perpetuated by all writers on posture for nearly a hundred years crept into the Committee's report. This error consisted in representing back curves as static, unchanged in profile views, while the abdominal outline is seen to be gradually cut away from the heavy through the intermediate to the slender body type. These three body types illustrate the classification used by Goldthwait and others of the "Eastern school" of posture.

Hippocrates described two fundamental types of man and called them the *phthisic habitus* and the *apoplectic habitus*. The former had a long, thin body and the latter a short, thick one. Since that time, each generation of medical observers has postulated some classification of body types.

Kretschmer conceived man as represented by three types; these were the *asthenic*, the *athletic*, and the *pyknic*. Each term speaks for itself. Many other terms have been suggested by those especially interested in man's basic temperament.

Viola arrived at a trunk volume and extremity index to determine a body-build index. Beneke and di Giovanni each measured many components of man's body and developed a disease classification based upon their indices. This was the age of superanthropomorphic measurements prior to the introduction of good photogrammetry.

Draper described a classification of body types on a disease-bearing foundation with each constitutional type or body build (the two terms are used interchangeably) particularly susceptible to certain diseases. This applies to orthopaedic disturbances as well.

Thieme found that the athletic type, the muscular or the intermediate body-build, was more prone to intervertebral-disc degenerations and protrusions. This was indicated by the degree of lumbar lordosis in his roentgenograms. Friberg reports more protrusions in the cervical and lumbar spine where the lordosis is greater. It follows, therefore, that the greater the extension of a vertebral zone, the greater is the likelihood of degenerative processes and the higher is the incidence of a breakdown in that region. Postural stance must contribute to these syndromes.

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* The work related in this article was performed under Contract W-44-109-q.m.-2241 under the sponsorship of the Army Quartermaster Corps.

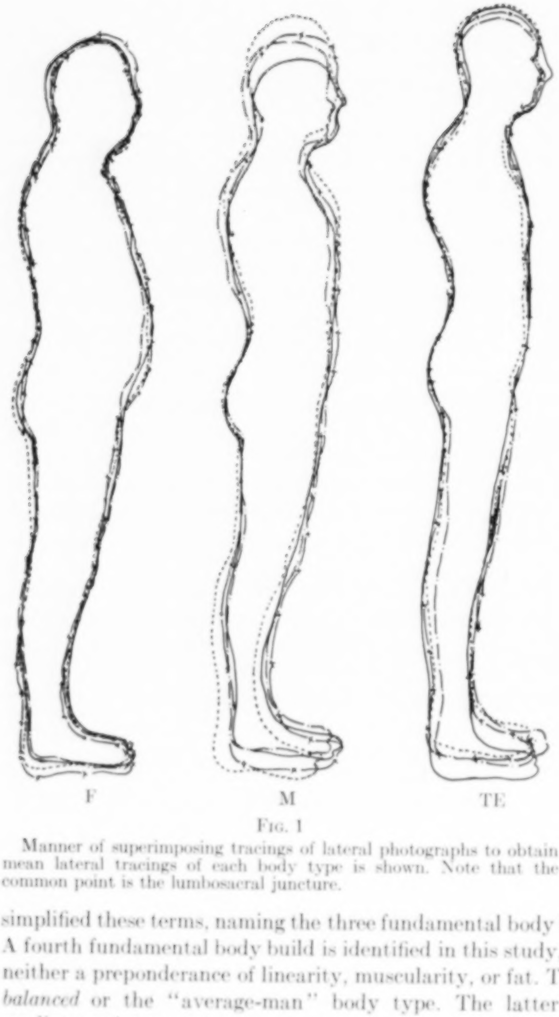

Fig. 1

Manner of superimposing tracings of lateral photographs to obtain mean lateral tracings of each body type is shown. Note that the common point is the lumbosacral juncture.

A normal position was described by Braune and Fischer, together with a relaxed and a military stance, under the guise of posture. They qualified their military stance as typifying an ideal posture on the basis of associated good health.

Morehouse and Cooper introduced interesting ideas concerning an acceptable normal posture, but then confused the reader by wandering into a highly speculative form of analysis.

Osgood, Klein, and their associates followed the leadership of Goldthwait and idealized the athletic or muscular body type.

In this paper, Sheldon's method as modified by Hooton was used to classify the body types of the large group of army photographs. Sheldon uses the terms *ectomorphic* to indicate the thin, elongated, or linear build, *mesomorphic* for the muscular or athletic type, and *endomorphic* to classify the stocky, horizontal, fat, or pyknic build. Hooton has simplified these terms, naming the three fundamental body builds *linear*, *muscular*, and *fat*. A fourth fundamental body build is identified in this study, which includes those who had neither a preponderance of linearity, muscularity, or fat. This type is called the *muscular-balanced* or the "average-man" body type. The latter term probably more closely applies to the type, because it existed statistically in the greatest number within this population sample.

Since the term "posture" is a purely subjective one, it may create almost any impression within the mind of the reader. Actually it is a much abused word. The author has expressed his conclusions as "orthograms", body outlines, and characteristic mean lateral posture patterns of the four fundamental body builds or constitutional types. These mean body-build patterns have been called "orthograms", suggested by their orthograde character and their dynamic nature.

MATERIAL

Standardized photographs, as introduced by Sheldon, Stevens, and Tucker, and Dupertuis, enable the constitutional type or body build of an individual to be rapidly assayed and to be assigned an accurate rating in terms of the three chief body components,—

the degree of fat, muscle, and linearity. This method of taxonomy depends upon three standard photographs,—full front view, lateral or profile view, and a full back view—all of which are carefully posed by the subjects on a special turntable.

Values of 1 through 7 were given each body component. Thus an individual who manifested a balanced body build—that is, one with neither too much nor too little of each of the three components—was given a 4- 4- 4 rating.

This method of photogrammetry offers a solution to the language difficulty when one is trying to describe with accuracy the body build of an individual. Sheldon also approximates the body-build determination or rating mathematically. An index is arrived at by dividing the height of the subject by the cube root of his weight. This index is then applied to a scale of values, and the numerical rating is obtained. Thus, observational, mathematical, and descriptive data are reduced to accurate and simple formulae. The anatomical panel, the morphology, or the somatotype of an individual can be reduced to a scientific symbol of great value as a descriptive research tool.

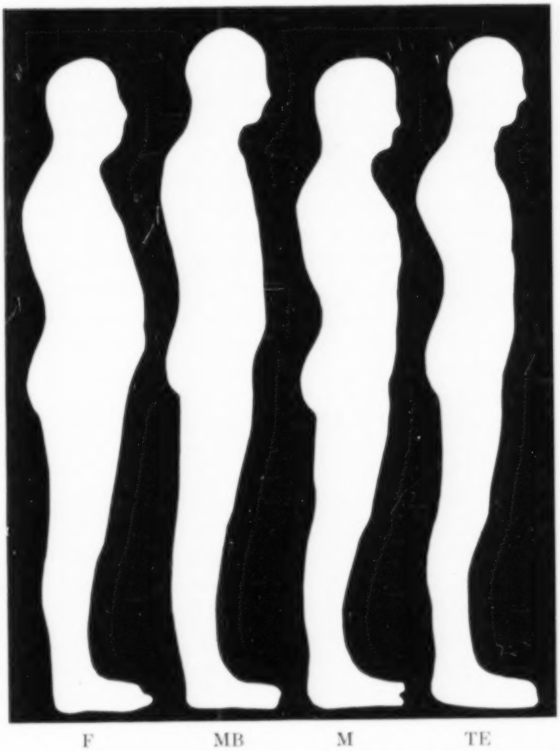

FIG. 2

Final mean tracings of the four body builds are shown as cutouts. F = fat, MB = muscular-balanced or "average-man" type, M = muscular type, and TE = thin, elongated type.

Thus, the slightly fat but moderately muscular and tall person would probably rate a symbol expressed as 2- 4- 4, while the moderately fat, slightly muscular, short person would be given a rating as 4- 3- 2. Descriptive terms rarely convey such exact meanings. The complex impression of the body pattern of man in terms of general outlines and composition of fat, muscle, and linearity can be reduced to a symbol, easily handled and appreciated by those who become conversant with the system.

A series of laboratories were set up by the Army Quartermaster Corps at separatee centers throughout the country, geographically placed for an objective sampling of the young male population. Nearly 100,000 young, adult, white males were photographed and measured by trained Army personnel, supervised largely by Dupertuis and Hooton. From this enormous group, 40,000 photographs were selected for the excellence of the photography, without in any way impairing the objectivity of the group selected. This group is probably the largest available for posture-study purposes. The examination and analysis of these photographs were done in the Statistical Laboratory, Department of Anthropology, Harvard University, under the supervision and the assistance of Prof. Hooton.

METHOD

Thirty-four hundred photographs, or roughly ten per cent. of the large group of 40,000 photographs, were selected as a fair sample of the series, constituting a workable group for laboratory procedures. Trained classifiers of body types selected at least seven photographs representative of the more than 100 somatotypes described by Sheldon and modified by Hooton. These were projected by a stereopticon which brought each to a standard ten-inch image. The lateral photograph was traced onto thin paper. This method made it possible to superimpose tracings so as to obtain the mean for each body type. The lumbosacral juncture in each tracing was used as the common point for superimposition. This area was selected because of the relative similarity of soft-parts thickness in most persons and because it is approximately the center of the body in the longitudinal plane.

Four samples were chosen to cover the range of all types of body builds with as great a degree of objectivity as possible. Mean tracings were obtained for each group and for each type, which were superimposed by independent classifiers, and the final mean tracings or "orthograms" were obtained for each general body type. A total of 3,400 photographs were inspected and 483 tracings were made.

INTERPRETATION

The final mean orthogram of each body build proved to be astonishingly characteristic of that particular constitutional type. The illustrations speak for themselves and must be considered to be truly representative. Likewise, the particular postural stance of each body build must be considered a normal for that type of person. Only one type, the muscular, represents our formerly considered "ideal posture" stance. The other types, apparently, cannot normally assume such a stance; it follows, therefore, that one should not expect them to do so. Each type has its obvious mean and will resist well-intentioned efforts to change. The thin, elongated, or linear type cannot assume the posture position of the muscular type; and the balanced type represents good posture, although it presents a less pleasing appearance than the muscular type.

Of course a "mean" is an abstraction and probably does not exist in life, occurring only in statistics. Yet in the sense intended in this study, the validity of a mean can scarcely be questioned. The four fundamental body types are composites and represent body builds as they really exist in a large sample of the population.

STATISTICAL ANALYSIS

The percentages of these four body types, as represented in the total series selected, were: fat type, 10.99 per cent., muscular type, 10.87 per cent., thin-elongated type, 18.00 per cent., and the muscular-balanced or "average-man" type, 26.02 per cent. (The muscular-balanced type was the modal type, the "central tendency" of the series.) The remaining body builds were all grouped under the general classification "intermediate types" (34.12 per cent.). The intermediate types were scattered throughout the 100 somatotypes and represented a distribution ranging between the fat type and the thin-elongated type. They were too few to have statistical significance, except that there were no full-blown representatives of the two extreme types.

CORRELATIONS

A recent monograph on posture by Ackerblom suggested the use of the tracings obtained in this study for checking the observations made by him.

Ackerblom sought data on standing and sitting postures for the construction of seats. He objected to Hooton's conclusion that "a soft cushion permits molding to fit practically any back shape". To accomplish a satisfactory analysis of sitting postures, Ackerblom first analyzed the "restful standing position". He concluded that either "the flexor muscles of the leg at the knee or the ligaments limit extension and determine the position of the knee joint when in a resting standing position, while the extensor muscles only come into action occasionally". Electromyographic studies of the part played by the thigh muscles in posture were made by the author which demonstrated the same findings.

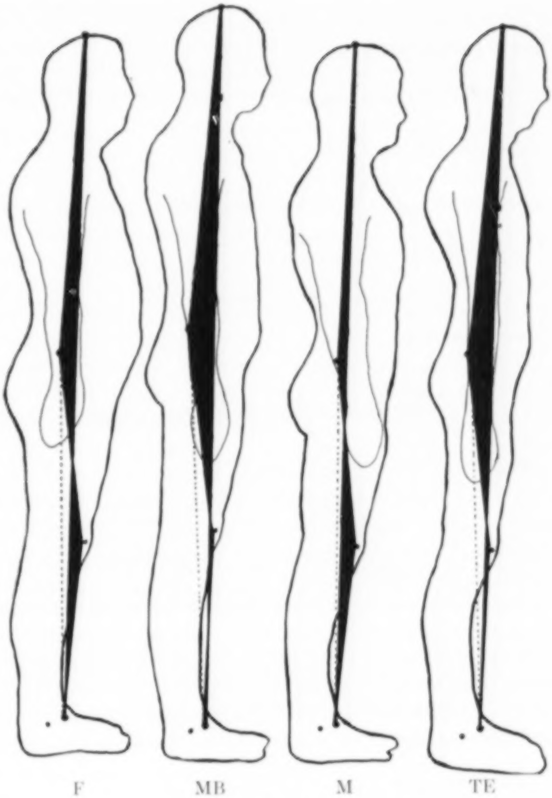

Fig. 3

Blacked-in areas form polygrams characteristic of each general body build. The dotted line is after the method of Ackerblom.

In order to locate Ackerblom's points of reference on the tracings, 100 lateral roentgenographic studies of white males, selected according to the Sheldon-Hooton classification, were made with the subjects posed in the standing position. These men were chosen from the records in the author's private and clinic files, according to their respective body types. Sheldon's formula of the height divided by the cube root of weight was used to check body-type determinations which had been made by clinical inspection. The lateral roentgenograms were taken with the subject posed in the same position as used by the army to pose subjects for its series of body-build photographs. In the roentgenograms, the shadows of the soft parts followed so well the underlying bony structures of the spine that the outline of the back could be considered to indicate the outline of the vertebrae. An occasional prominent scapula or a protruding buttock did not prevent good correlations. These lateral roentgenograms enabled the reference points used by Ackerblom, Fischer, Schwartz, and Howorth to be plotted accurately on the tracings. It would otherwise have been difficult to locate the anterior margin of the body of the first sacral vertebra or the head of the talus on a lateral tracing of a photograph.

The mean position of the anterior margin of the body of the first sacral vertebra was found to be four-tenths the distance between the center of the curve at the lumbosacral juncture and the groin, measuring from the shadows of the soft parts, which were easily demonstrated on plates of light density. The patella was readily identifiable on the tracings by the characteristic anterior bulge at the knee joint, while the head of the talus was located with the aid of later roentgenographic studies of the feet of white males bearing full weight. The lateral malleolus was shown to be located at a point in the center of the diameter of the narrowest portion of the leg at the ankle.

A line was then dropped perpendicularly to the horizontal plane from the cranial vertex, representing the direct pull of gravitational forces on the body as a whole. This was called the center-of-gravity line which is drawn from the vertex to distinguish it from

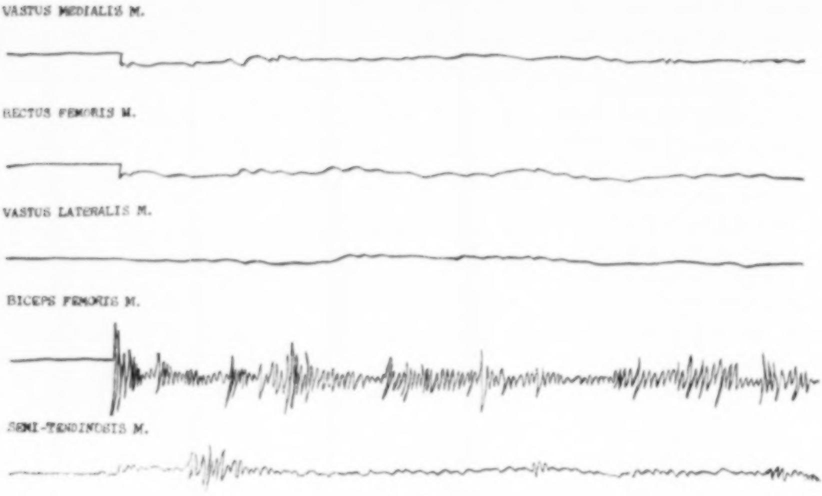

FIG. 4

Electromyographic studies of thigh muscles, for which the subject has been posed with his feet and knees together, show considerable muscle activity of antigravity muscles, — the biceps femoris and the semitendinosus. (After the methods of Sullivan, Duchenne, and Goff.)

a second line, drawn according to the method of Ackerblom, from the body of the first sacral vertebra to the anterior margin of the head of the talus. This line is represented by the dotted lines in Figure 3. When lines were drawn from the vertex to the anterior edge

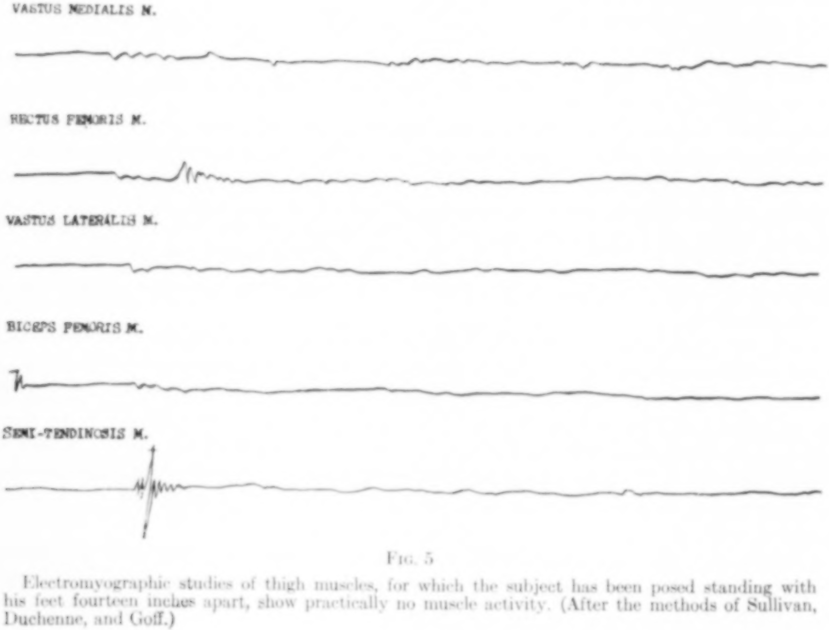

FIG. 5

Electromyographic studies of thigh muscles, for which the subject has been posed standing with his feet fourteen inches apart, show practically no muscle activity. (After the methods of Sullivan, Duchenne, and Goff.)

of the sacrum and from the sacrum to the middle of the patella and from the patella to the head of the talus, two polygrams were formed. Blacked in, they formed a characteristic pattern for each of the four body types. These polygrams represent a rapid and graphic manner of demonstrating differences in the lateral view, the one generally used when orthograde posture is investigated.

Ackerblom, in determining the line of gravity, used the balanced divided scale on which the subject stood in an easy standing position. Roentgenograms were taken with a steel plumb line suspended directly over the head of the talus. This line passed through the knee joint 1.5 centimeters ± .02 centimeter behind the articular surface of the patella; through the dead center of the hip joint (acetabulum), and through the anterior margin of the head of the talus. Many investigations have shown that this is the usual center-of-gravity line located in the lateral view of the subject standing erect and at ease with his feet close together.

A line drawn from the promontory of the sacrum to the highest point of the cranial vertex in the author's series of mean tracings always sloped forward. This angle is greatest in the thin-elongated type, least in the muscular type, and midway between the two in the fat type.

According to Howorth's illustrations, the mechanical arrangement of body levers describes a Z-like system. Slightly flexed knees and hips with the body gently inclined forward is considered by him the essential "dynamic posture position". The human mechanism, assuming such a position, is keeping the center of equilibrium slightly forward, poised,—a position in which the muscles can act quickly and efficiently. Ackerblom's center-of-gravity line, drawn upon the four mean tracings of this large series, passes considerably behind the articular margin of the patella. This indicates a lack of complete extension at the knee and hip, resulting in a dynamic posture stance as illustrated by Howorth. Without the inclusion of these center-of-gravity lines, the lateral tracings fail to give this impression. The vertex-sacrum line is the top of the Z, while the talus-patella line is the lower arm of the Z. The patella-acetabulum-sacrum line joins the two.

Electromyographic studies of Duchenne, Ackerblom, Sullivan, and the author show activity of the calf and thigh muscles, especially the antigravity groups, when the body is posed with the feet close together in the erect, standing-at-ease position, and show practically no muscle activity in these same groups when the body is posed with the feet fourteen or more inches apart in a similar stance. Typical electromyographic tracings are reproduced in Figures 4 and 5. As previously stated, when the body is posed in the first position, the center-of-gravity line passes through the condyles of the femur at the knee joint, about 2 centimeters behind the articular surface of the patella. In the second position, mild hyperextension takes place, together with the final screw-home movement at the knee and the center-of-gravity line passes through the patella. The muscles act as ligamentous blocks in the second position and the stance is therefore not truly dynamic.

The mean tracings of this large army group correlate well with the first position in which the feet are close together. This posed position is described by Sheldon as that of a soldier standing at attention, alert, and yet in no way tensed. A dynamic position is clearly indicated.

Kelton and Wright have reported additional substantiating data. In the "easy standing" position, man depends chiefly upon mechanical arrangements at the knee but less so at the ankle. At the ankle joint, equilibrium requires greater muscle activity of the balancing, antigravity muscles,—the soleus and the tibialis anterior.

CONCLUSIONS

Mean lateral tracings of a statistically valid sample of body-build photographs show lateral posture positions which must be considered characteristic of each body type. The term "orthogram" is suggested to indicate the manner of arriving at these posture patterns. These are characteristically dynamic, correlating well with the work of Ackerblom, Howorth, Duchenne, Sullivan, and Kelton and Wright.

This study establishes the determination of posture on a scientifically sound basis, and it should be given priority when defining the normal posture of young, adult, white males, standing at ease. This should be of basic interest to the orthopaedic surgeon.

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EXPERIMENTAL RUPTURES OF INTERVERTEBRAL DISCS IN RATS' TAILS

A Preliminary Report

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PREMISES

The premises on which the experiments to be presented were based were as follows:

1. Discograms—that is, roentgenograms of discs injected with a contrast material—demonstrated that in early stages of disc ruptures a more or less radial rupture extended through the annulus, while the nucleus, on the whole, appeared normal. In microscopic sections of the annulus in the region where such radial ruptures occurred, the normal network of fibrous bundles (Fig. 1) was replaced by irregular nodules of a more homogeneous appearance (Figs. 2, 3, and 4). The extent of these structural changes was far greater than the ruptures themselves. It was therefore suggested that the structural changes were primary to the ruptures.

2. The radial ruptures and the structural changes in the annulus already described were more common in the dorsal portion of the lower lumbar discs where the axial pressure on the disc is greatest.

3. In a roentgenographic and anatomical study of 160 lumbar portions of spines of cadavera, a correlation was found between disc ruptures and marginal osteophytes. Such

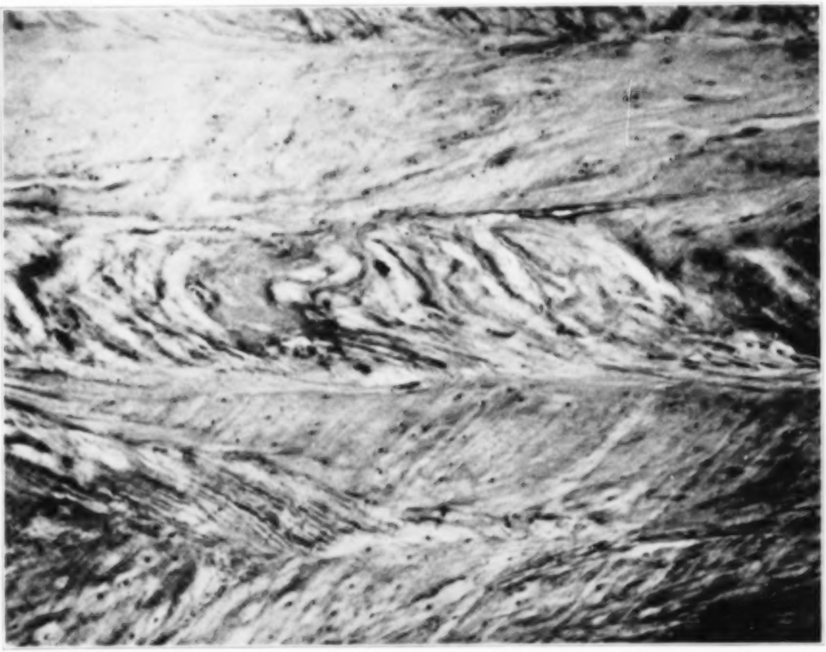

Fig. 1

Photomicrograph (× 100) of annulus fibrosus in man, demonstrating normal network of fibrous bundles.

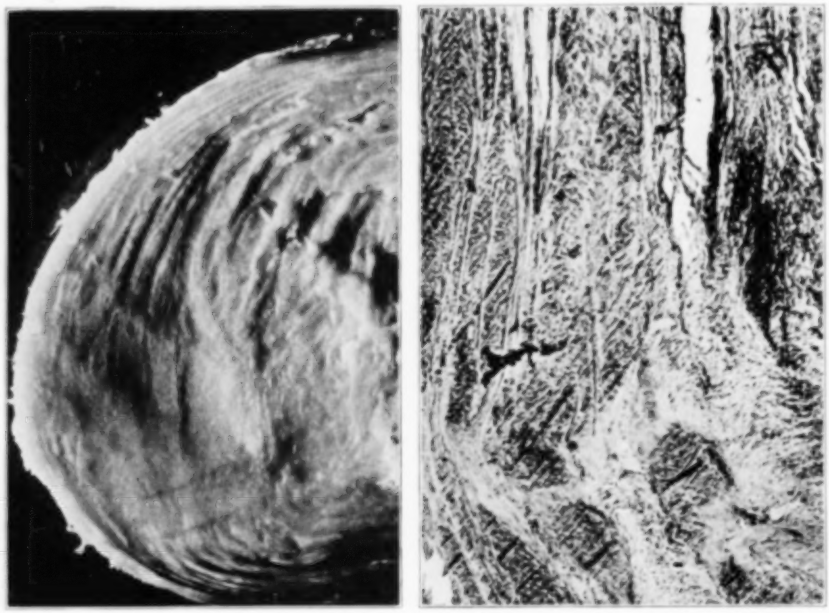

FIG. 2 FIG. 3

Photograph (× 2) and photomicrograph (× 50) of annulus fibrosus in man, demonstrating partial replacement of fibrous bundles by a more homogeneous tissue.

osteophytes were present only in ruptured discs and the extent of bony formations was, as a rule, dependent upon the extent of disc change. Thus, the occurrence of osteophytes was an indication of disc degeneration and rupture. This fact was used in a comparative study of the lumbar portion of the spine taken from a modern population on the one hand and a prehistoric population on the other. The result of this comparison was as follows: Modern man has more and larger osteophytes in the lower lumbar region than prehistoric man; at the lumbosacral disc the occurrence was higher in the modern female than in the male, while this difference was not found in the prehistoric material. It was therefore supposed that something in the modern way of living (such as wearing shoes with heels) increased the lordosis, which resulted in increased pressure on the posterior portion of the lower lumbar discs.

MATERIAL, TECHNIQUE, AND RESULTS

With these three premises, experiments were carried out on a series of rats' tails in order to study the effect of constant asymmetric pressure on the intervertebral discs.

The tails were tied up and fixed in the shape of a U. The time of fixation ranged from two weeks to six months. At the end of this period the tails were fixed in formalin, embedded in paraffin or celloidin, and sectioned.

In the first three series of the experiments, in which thirty-four discs from twelve tails were used, the discs were sectioned parallel to the surfaces of the adjacent vertebrae. In some of these sections structural changes were present on the compressed side, but no rupture was demonstrable.

However, in one of those twelve tails which had been fixed for five months, longitudinal sections paralleling the U shape were made of one disc together with the adjacent bone. Microscopic studies revealed a rupture of the annulus on the compressed side. The rupture ran through a necrotic annulus and ended in granulation tissue at the surface of the disc.

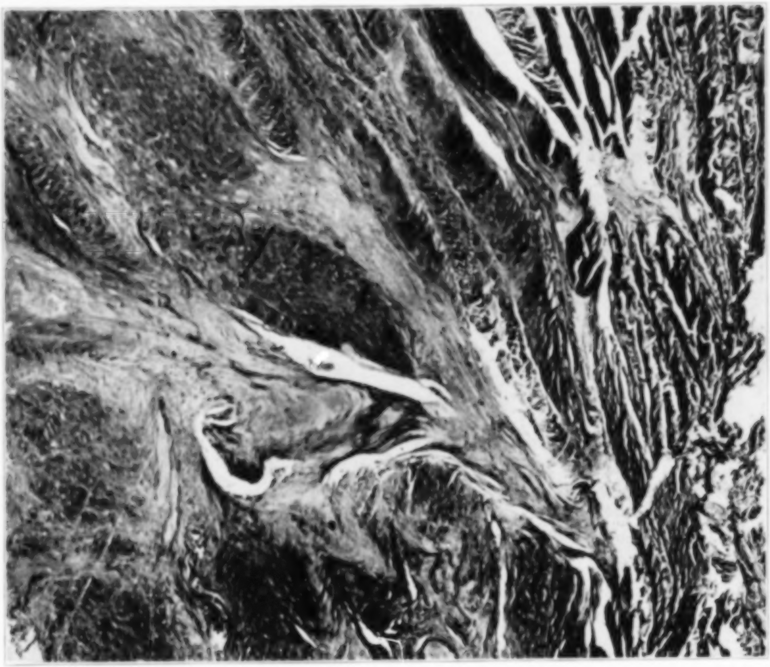

FIG. 4

Photomicrograph (× 22) of ruptured disc in man, illustrating partial disappearance of fibrous bundles in region of rupture (to the right).

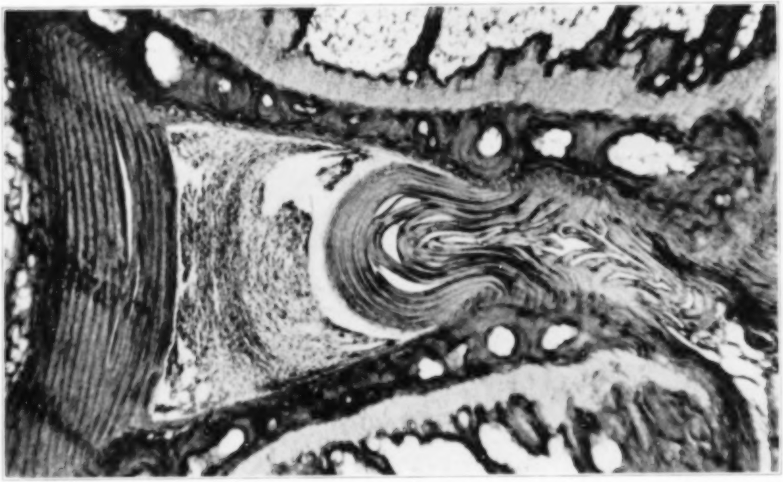

FIG. 5

Photomicrograph (× 80) of celloidin section of compressed and ruptured disc in rat's tail. Compressed side to the right.

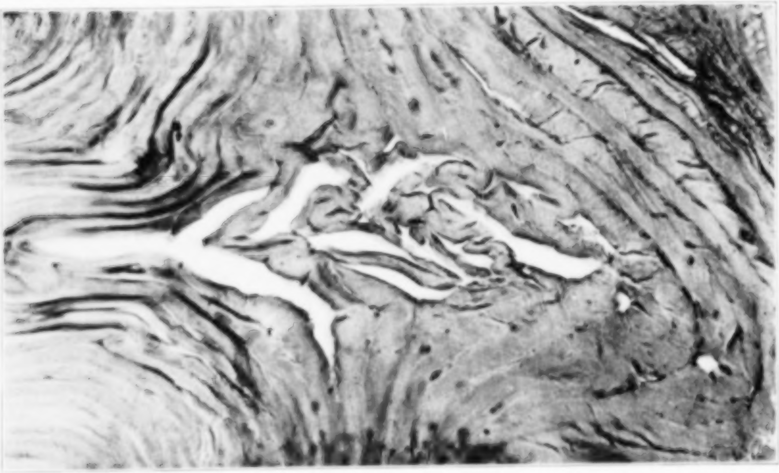

FIG. 6

Photomicrograph (× 200) of same disc as in Fig. 5. Note deformation of compressed bundles.

In a fourth series, consisting of three tails tied up and fixed in the same way for two and one-half to three months, the tails were decalcified and sectioned parallel to the U. The specimens included fourteen compressed discs altogether. The tails were first embedded in paraffin and then sectioned down to the mid-plane of the discs, after which the remaining half of the specimens were treated with benzol and embedded and sectioned in celloidin.

Those parts of the tails which were proximal and distal to the curve of the U served as control material.

In this fourth series all the discs in the curved parts of the tails showed structural changes on the compressed side with more or less extensive rupture through the same region. The discs outside the curved part presented no such changes.

The structural changes on the compressed side are illustrated. The types of changes were as follows:

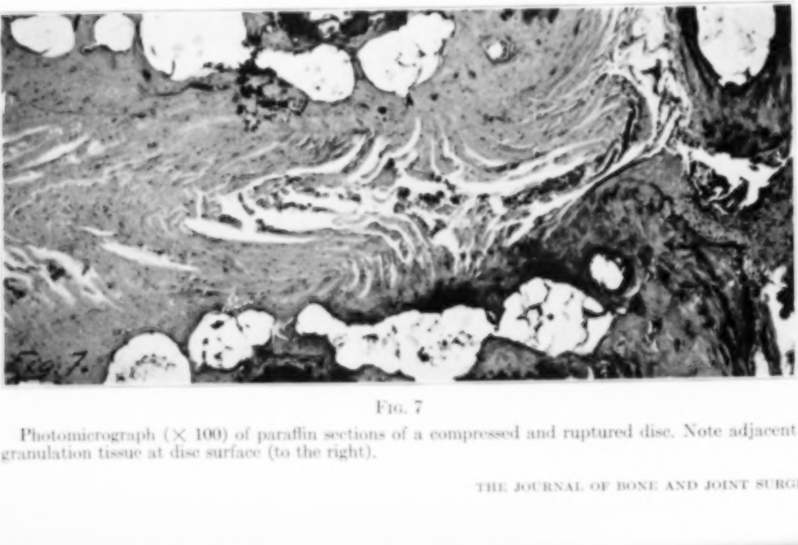

FIG. 7

Photomicrograph (× 100) of paraffin sections of a compressed and ruptured disc. Note adjacent granulation tissue at disc surface (to the right).

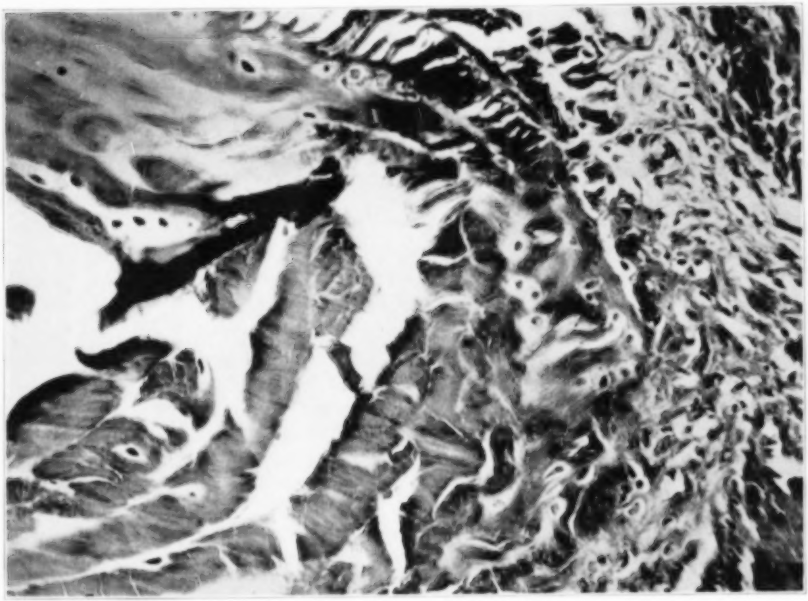

FIG. 8

Photomicrograph (× 250) of paraffin section of another compressed and ruptured disc in a rat's tail. Note granulation tissue (to the right).

1. The fibrous bundles became curved and swollen for a short distance beyond their attachment to the bone, then grew narrow and irregular and were finally interrupted (Figs. 5 and 6). The rupture ran parallel to the vertebral surfaces through the compressed side of the annulus; in four discs the rupture extended through the outermost layers of the annulus where it reached granulation tissue (Figs. 7 and 8).

2. Such granulation tissue at the surface of the disc was only found on the compressed side and only in cases where the rupture extended to a point very close to the disc surface or actually perforated the surface. In the contact area between the annulus and the granulation tissue, parts of the protruding bundles had disappeared (Fig. 9).

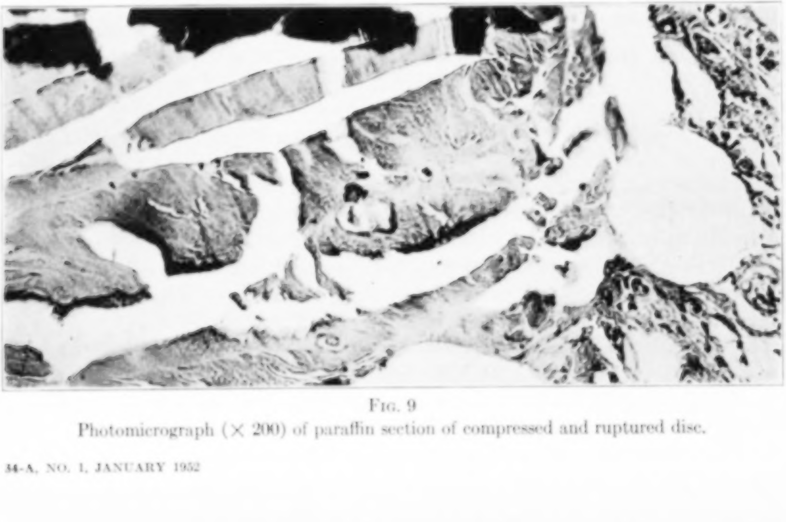

FIG. 9

Photomicrograph (× 200) of paraffin section of compressed and ruptured disc.

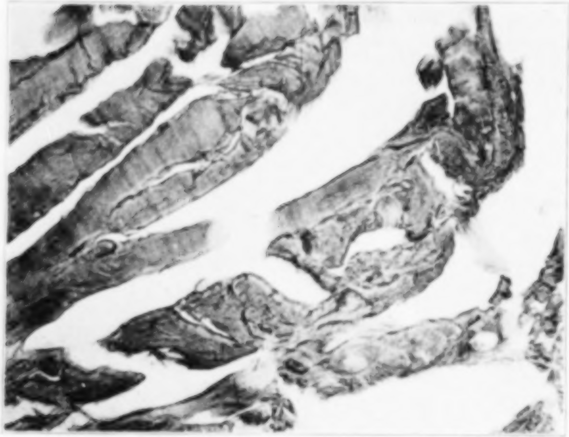

FIG. 10

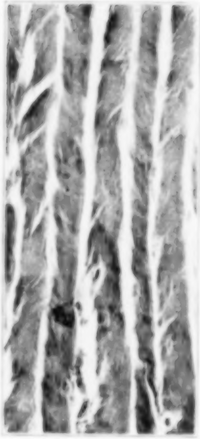

FIG. 11

Fig. 10: Photomicrograph (× 200) of paraffin section of a compressed and ruptured disc. Note degeneration of annulus bundles in this disc and in the disc shown in Fig. 9, and compare with structure of bundles in Fig. 11.

Fig. 11: Photomicrograph (× 200) of paraffin section of non-compressed side of annulus in same experimental animal as in Fig. 9. Normal structure of annulus bundles.

3. The narrowed and broken as well as the swollen sections of the curved bundles showed a definite decrease in the number of nuclei. Some of the remaining nuclei were swollen (Figs. 9 and 10). In these bundles the normal fibrillar structure (Fig. 11) was lacking and the bundles appeared almost homogeneous (Figs. 9 and 10).

In the discs embedded in celloidin, the fibrous bundles next to the nucleus pulposus were not ruptured. The nucleus was slightly deformed but appeared otherwise normal.

On the stretched side a definite pathological change in the annulus occurred in only one disc. In this disc a wedge-shaped mass of young fibrous tissue was interposed between the bony attachment and the bundles of the annulus. This was believed to be a callus formation because of rupture of the annulus attachment when the tail was tied up.

No bone reaction was seen in the specimens.

DISCUSSION AND CONCLUSIONS

The rat's tail is a spine in which the only pressure on the discs is caused by muscle contractions. The tail is not weight-bearing and cannot be adequately compared with the human spine. However, the pressure exerted by muscles is greater than that exerted by body weight. In accordance with this, disc degeneration and rupture occur frequently in the spine of several animals.

Even if a comparison between the forces acting on the disc in animals' tails and in the human spine is justified, the conditions in these experiments were not sufficiently like normal physiological conditions for definite comparisons to be made between normal and experimental ruptures.

In order to obtain a more reasonable correspondence, experiments are now being made in which tails are curved and tied up in the same direction for a short period of time every day. Additional experiments are being made in which the tails are fixed for longer periods of time than any in the present series.

The only definite conclusions which can be drawn from the present results are as follows:

1. It is possible to produce degeneration and rupture of the annulus fibrosus of the intervertebral disc by constant compression of one side of the annulus.

2. This degeneration and rupture takes place without change in the nucleus pulposus.

ARTHRODESIS OF THE FIRST METATARSOPHALANGEAL JOINT FOR HALLUX VALGUS, HALLUX RIGIDUS, AND METATARSUS PRIMUS VARUS

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The multiplicity of procedures devised for the radical cure of hallux valgus, metatarsus primus varus, and hallux rigidus, and the failure of any one of them to become generally accepted as the best procedure for these conditions, would indicate that none of them yields a high percentage of good results. Some of the fascial and tendinous sling procedures for the correction of metatarsus primus varus are undoubtedly applicable in young patients and will produce satisfactory results; however, only the test of time will determine whether they will prevent the ultimate development or recurrence of the hallux valgus and its accompanying disability. Correction of varus of the first metatarsal must continue to be essential in any operation for hallux valgus which hopes to yield a permanent correction. The principle inherent in the McBride operation would seem to be the only anatomically reasonable contribution so far to functional correction of this deformity.

Hallux rigidus is a definitely disabling condition, of frequent occurrence, which may produce severe disability in some cases. No form of corrective surgery has ever been quite satisfactory in this condition. Ligamentous and tendinous contractures and adhesions of the first metatarsophalangeal joint which accompany the condition preclude the restoration of a satisfactory functional range of motion.

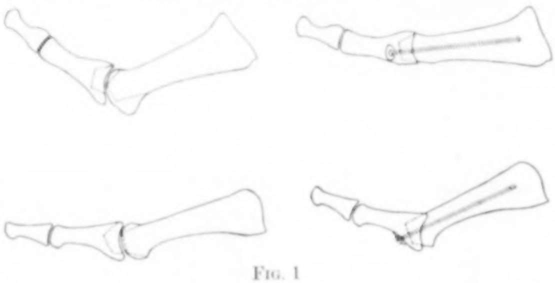

FIG. 1

Schematic drawing showing the amount of bone removed and the angle of fixation in both planes.

About 1941, the author performed a bilateral operation for hallux valgus. Infection ensued on one side and the resultant scar-tissue formation produced an extremely rigid fibrous ankylosis of the first metatarsophalangeal joint. When weight-bearing was resumed, it was noted that the metatarsus primus varus was much less extensive on this side and that from a functional standpoint, both by subjective and objective evaluation, this was much the better foot. The obvious conclusion was that ankylosis of this joint would relieve pain after the manner of ankyloses elsewhere in the body.

In 1943 and 1944, a few arthrodeses of this type were performed on men in the service; while the results seemed eminently satisfactory at the time and the patients returned to duty, a long-term follow-up was impossible and the ultimate end results are unknown.

Late in 1945, the writer began to use this operative procedure on private patients, at first on patients with hallux rigidus and with severe degrees of hallux valgus. Experience with a series of thirty-three patients with fifty-six feet involved has led to the elimination of most of the pitfalls which may be encountered in this operation and to the development of a technique which will produce arthrodesis in an extremely high percentage of cases. This technique is presented here for general consideration; however, it must be stressed that it is the arthrodesis and its position that is important and not the method by which it is produced (Fig. 1).

The author prefers a medial linear incision slightly toward the plantar surface. The incision may also be made directly medial or toward the superior surface. This incision may be extended from the interphalangeal joint proximally to about the central portion

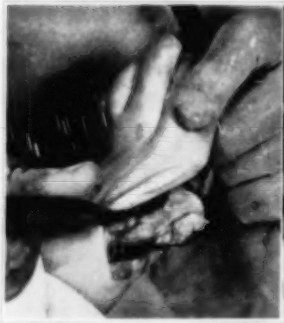

FIG. 2-A

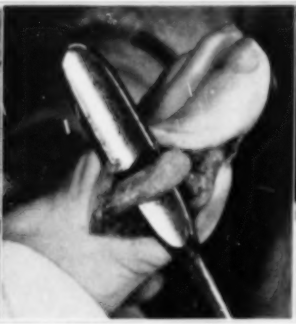

FIG. 2-B

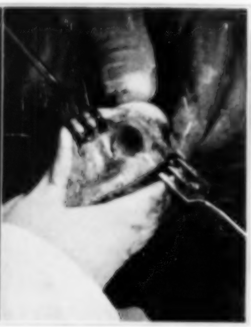

FIG. 2-C

Fig. 2-A: The head of the metatarsal bone is disarticulated.
Fig. 2-B: Metatarsal after removal of bone.
Fig. 2-C: A hole is drilled and reamed out at the base of the proximal phalanx.

of the first metatarsal, or a somewhat shorter incision may be made over the joint, with a small separate incision on the plantar surface for the insertion of the internal fixation screw. The proximal one-fourth inch of the proximal phalanx on the medial side and the distal one inch of the metatarsal are denuded of periosteum and ligaments, and the joint is completely disarticulated (Fig. 2-A). The distal end of the metatarsal is then cut down to a blunt point with an osteotome (Fig. 2-B). The first metatarsal is osteotomized in a distal direction in order to avoid splintering. The procedure requires the removal of a

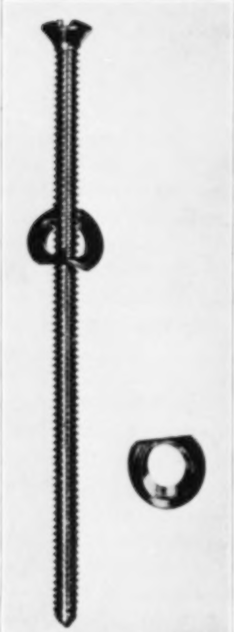

FIG. 3

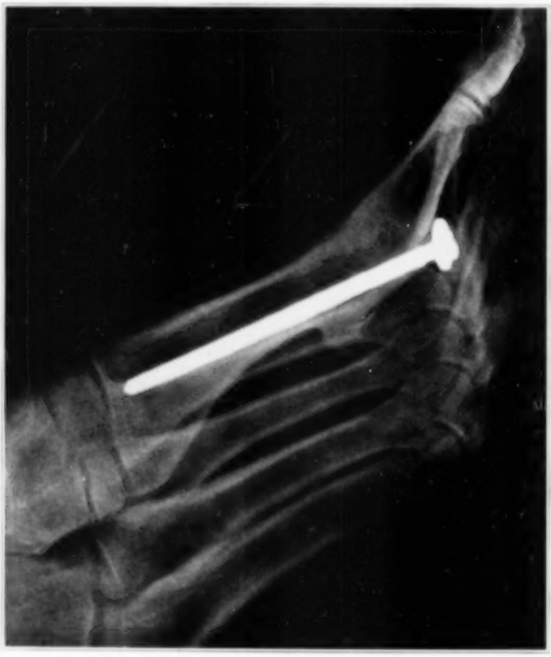

FIG. 4

Fig. 3: A screw and special washer. The narrow side of the washer goes toward the bone and away from the plantar surface.

Fig. 4: Lateral roentgenogram showing the length and position of the screw and the arthrodesis.

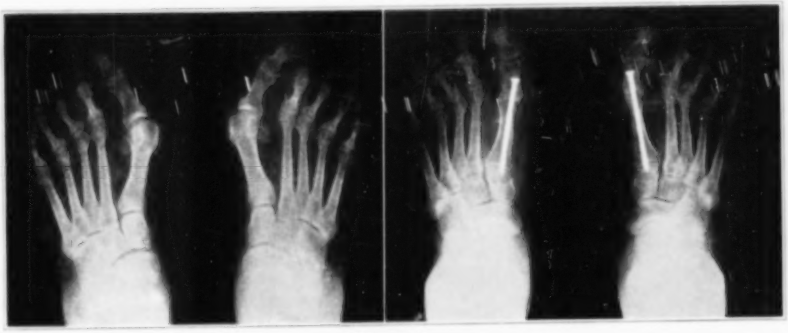

FIG. 5-A

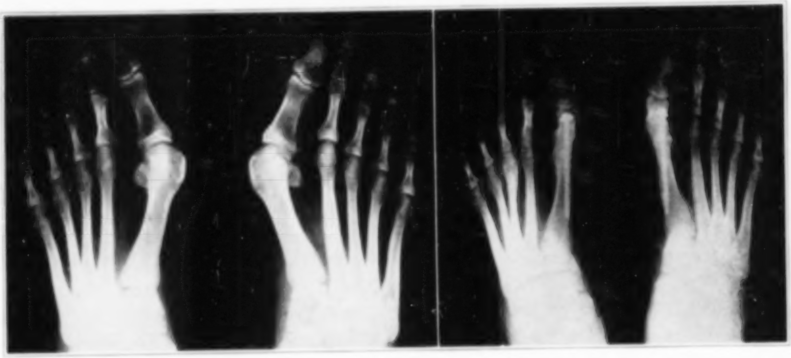

FIG. 5-B

Figs. 5-A and 5-B: Preoperative and postoperative roentgenograms made while the patient was bearing weight. Note correction of varus of the first metatarsal.

large quantity of bone around the head of the metatarsal. The tip, when finished, is about three-eighths of an inch in diameter and slopes at a rather sharp angle back to the neck of the metatarsal. A hole one-fourth of an inch in diameter is then drilled in the base of the proximal phalanx. This hole should not be over three-eighths of an inch in depth. It is then reamed out to a conical shape, corresponding to the shaped end of the metatarsal, with a small motor-driven reamer (Fig. 2-C). This bone is extremely hard and must be cut slowly to avoid overheating. A Kerrison punch may be found useful here. Exposure of the plantar surface of the proximal phalanx is obtained either by means of extending the single incision or by making a small separate incision.

It is now necessary to determine the angle of arthrodesis between the first metatarsal and the proximal phalanx. In the sagittal plane, this is determined by pressing the first metatarsal as close as possible to the second metatarsal and then putting the first and second toes side by side. In the coronal plane, the angle varies according to the anticipated function (Fig. 1). In men it will be approximately 15 to 20 degrees of extension. In women who habitually wear shoes with medium heels it will be from 15 to 25 degrees and in women who wish to wear high-heeled shoes at all times it may be as high as 35 degrees.

While the toe is held in the position required, a hole is drilled which starts at the middle of the plantar surface of the proximal phalanx and crosses into the medullary canal of the shaft of the first metatarsal. A stainless-steel screw with a small curved oval washer is then inserted into the drill hole (Fig. 3). The screw should be long enough to extend almost the full length of the shaft of the first metatarsal, as rigid fixation is difficult

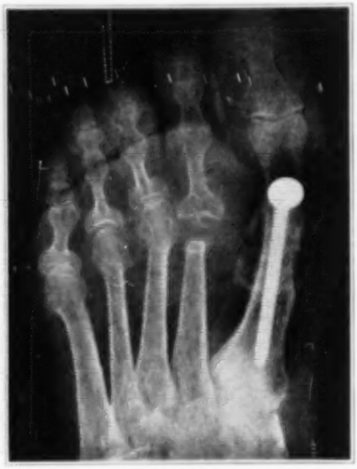

FIG. 6

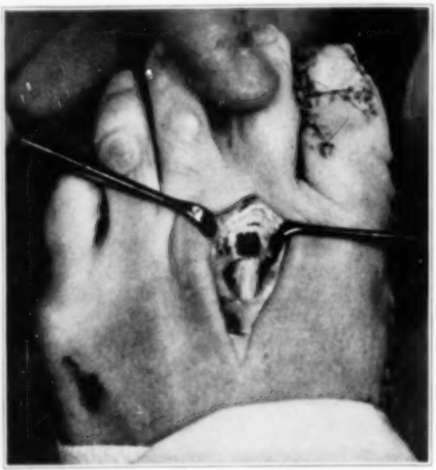

FIG. 7

Fig. 6: Roentgenogram made after an operation for hallux valgus. The second metatarsal head was resected because of subluxation.

Fig. 7: The second metatarsal head was cut off and was reamed out after the bunionectomy was completed. The great toe nail has been removed. The extensors of the other toes are to be tenotomized.

to obtain with a short screw because of lack of purchase on the first metatarsal. The washer is necessary in order to prevent the head of the screw from pulling through the thin cortical bone on the plantar surface of the proximal phalanx. Lack of foresight in these matters resulted in the five failures of arthrodesis in the writer's series. The incision is then closed and any superfluous skin and subcutaneous tissue are resected to ensure a smooth closure. There is usually a considerable amount of resection, as the entire joint and medial side of the foot have been made much smaller. If the medial sesamoid seems to interfere with the closure, it may be removed; it is the author's custom to do so, although it is not necessary.

A pressure bandage is applied to the foot. This bandage is loosened after four to six hours. It is replaced with a small dressing on the third or fourth day when weight-bearing in a cut-out shoe is permitted. The only precaution used is that the patient is not allowed to place his full weight on the toe at the end of the step for six weeks. The patient is cautioned very strongly about this and is given specific instruction in walking. As soon as the stitches have been removed and the swelling is sufficiently reduced, the foot is put into a shoe which is not cut out. After six weeks a normal gait is resumed and any type of shoe may be worn. About 50 per cent. of patients require no alteration in their shoes after the operation; the other 50 per cent. may require some metatarsal padding temporarily, and a few will require some metatarsal padding permanently.

It is necessary to call attention to the fact that in many cases the hallux valgus operation alone is not sufficient to produce a good result. Such deformities and conditions as hammer-toe, digital neuroma, soft corn, complete subluxation of lesser metatarsophalangeal joints, and marked discrepancies between the length of the metatarsals must be taken into consideration and corrected at the time when the operation for hallux valgus is performed.

Simple tenotomy of the extensors may suffice for flexible hammer toes, or a complete arthrodesis with an intramedullary pin or wire may be performed.

If a digital neuroma is found to be present, this should be removed.

If there is complete luxation of a lesser metatarsophalangeal joint, resection of the head of that metatarsal is advisable. Luxation is fairly common in the more severe cases of metatarsus primus varus and in hallux valgus (Fig. 6).

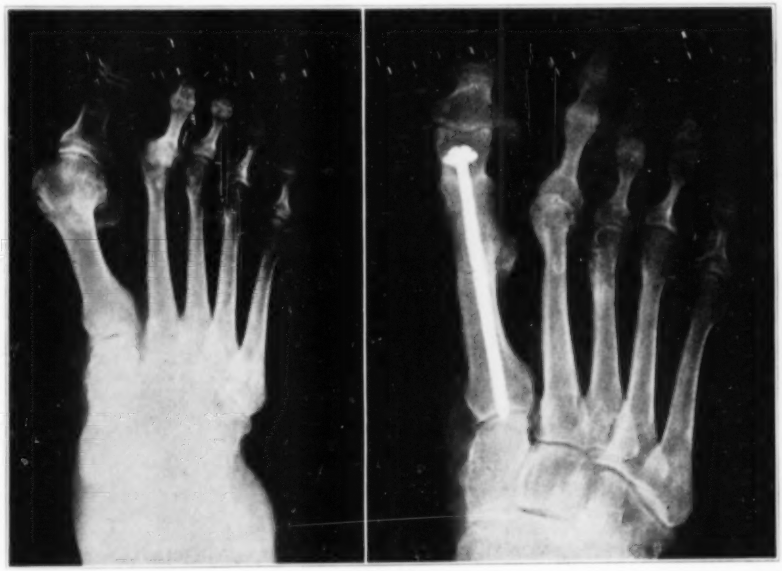

FIG. 8

Roentgenograms made before and after an operation for hallux valgus with shortening of the second and third metatarsals.

An operation for the correction of discrepancies in length of the lesser metatarsals will be described in somewhat more detail. In many cases of hallux valgus there is a marked concentration of weight-bearing on the second metatarsal head, and this is not completely relieved by the operation for hallux valgus. The most satisfactory relief is afforded by relative shortening of the second metatarsal shaft. Shortening can be carried to a point of completely relieving the metatarsal head of all weight-bearing if necessary, without interfering with the function of the metatarsophalangeal joint. This procedure is also successful in relieving plantar wart under the second metatarsal head, and in one case has been used to stop a progressive infraction of the second metatarsal head. At times it may be necessary to apply it to the second, third, and fourth metatarsals in order to produce an equitable distribution of weight in the metatarsal area.

Basically, the operation consists of a telescopic shortening of the second metatarsal shaft in order to relieve a metatarsal bone of excessive stress imposed by weight-bearing. The technique is as follows: A small dorsal linear incision is made over the distal portion of the metatarsal shaft and dissection is carried down to the neck of the metatarsal. This is osteotomized transversely, a procedure which is easily carried out if a straight-blade saw of the reciprocating type is used. The cut must be made with a power saw or a Gigli saw; shear-type cutters used at this level will splinter the bone. A drill with a diameter of three-sixteenths or one-fourth of an inch is then used to hollow out the head of the metatarsal to the depth required for the degree of shortening desired (Fig. 7). The distal end of the shaft is pointed slightly and telescoped into the head. The amount of shortening can usually be determined by measurements made on roentgenograms taken before the operation (Figs. 8 and 9). Internal fixation is not necessary, even if the second, third, and fourth metatarsals are shortened at the time of the operation for hallux valgus. It is not necessary to alter the postoperative routine, although the foot remains somewhat thickened for a number of weeks after the operation.

The technique described is offered for the relief of hallux valgus, metatarsus primus

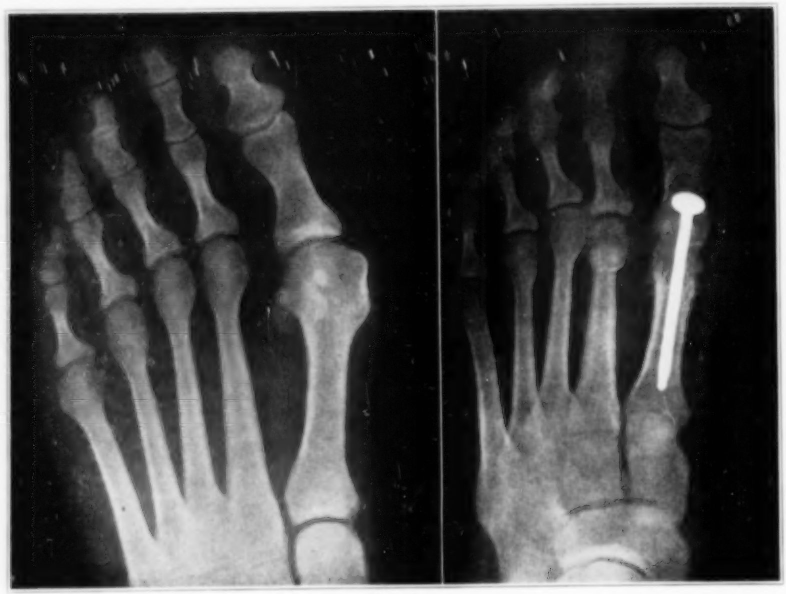

Fig. 9

Roentgenograms made before and after an operation for hallux valgus with shortening of second metatarsal.

varus, and hallux rigidus, and for certain associated defects in cases where more than a simple removal of an exostosis is necessary. The greater the deformity, the more satisfactory this solution seems to be. It is readily applicable in cases in which previous attempts at surgical correction have been made and may be confidently offered as a permanent cure of the deformity. Surgical correction of accompanying functional and structural defects is recommended because these defects cannot be ignored if permanent good results are to be obtained.

The literature reveals that Thompson and McElvenny[1], in 1940, reported on arthrodesis of this joint in cases of tuberculosis. They also suggested arthrodesis as a possible solution for certain types of deformity following poliomyelitis, for hallux rigidus, and for hallux valgus with complete dislocation. These authors described in considerable detail a method of obtaining optimum position of the arthrodesis.

The writer's experience with this method has been so favorable that he has adopted it as a standard procedure in all of the conditions mentioned. If arthrodesis is obtained and the position is good, the result will be satisfactory both to the patient and to the surgeon. It should be noted, moreover, that even those patients in whom the arthrodesis failed have been completely comfortable after removal of the internal fixation, and so far the deformity has not recurred in any of these cases.

[1] Thompson, F. R. and McElvenny, Robert T.: Arthrodesis of the First Metatarsophalangeal Joint. J. Bone and Joint Surg., **23**: 555-558, July 1940.

AN UNUSUAL FORM OF OSTEO-ARTHROPATHY PRESENT BILATERALLY IN THE KNEES OF TWO BROTHERS

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The two cases reported herein are considered to be sufficiently unusual and perplexing, from the standpoints of etiology and diagnosis, to justify a record being made of them. For lack of a classifying name, the term "osteo-arthropathy" has been used.

REPORT OF CASES

CASE 1. A white youth, sixteen years of age, had always had good general health. He was first seen at the Mayo Clinic on December 14, 1945, at which time he gave a history of a moderately painful swelling of the left knee of three years' duration and of the right knee of three months' duration. In March 1943, the left knee had been operated upon elsewhere. The exact nature of the operation was doubtful. Subsequent to the healing of the wound, the patient had returned home and had been ambulatory without a brace or crutches. Several months later instability and angulation of the knee had been noticed, and in November 1944 he had been fitted with a brace. In May 1945, a hard mass had been detected on the medial aspect of the left knee. This slowly increased in size. The patient's mother, father, and three siblings were living and well. There was no history of tuberculosis or venereal disease.

TABLE I

RESULTS OF ANALYSIS OF FLUID FROM RIGHT AND LEFT KNEES

Analysis of Fluid	Right Knee	Left Knee
Sugar	100 milligrams per 100 cubic centimeters	100 milligrams per 100 cubic centimeters
Protein	3.8 grams per 100 cubic centimeters	4.2 grams per 100 cubic centimeters
Albumin-globulin ratio	3.46:1	2.38:1
Bilirubin, direct test	Negative	Negative
Bilirubin, indirect test	0.5 milligram per 100 cubic centimeters	0.6 milligram per 100 cubic centimeters
Culture	Negative for acid-fast organisms	Negative for acid-fast organisms

The physical examination revealed an ambulatory, well-developed, and well-nourished youth. The knee and ankle jerks were equal and active. The left leg was one inch shorter than the right leg, and the thigh, calf, and foot were markedly atrophied. All joints, with the exception of the knees, were normal on examination. Instability of the left knee was notable, together with tumefaction in the region of the medial condyle of the femur, lateral dislocation of the patella, and crepitus on motion. The right knee exhibited marked effusion with some anteroposterior and lateral instability and slight limitation of flexion. The patient was able to walk without pain.

Laboratory examinations revealed nothing of significance. Results of the flocculation test for syphilis and the tuberculin test were negative. The sedimentation rate (Westergren method) was 15 millimeters in the first hour.

Roentgenograms of the left knee (Figs. 1-A and 1-B) revealed epiphyseal arrest of the lateral border of the femoral condyles with marked roughening and some fragmentation of the epiphyses. Those of the right knee showed synovial thickening with early changes in the bony structure (Fig. 1-C).

On December 19, 1945, the right knee was explored, and it was found to contain much fluid. The synovial membrane was greatly thickened and was removed in its entirety. A panus had formed which extended down onto the femoral condyles. In the lateral pouch, two large fragments of cartilage were found which comprised

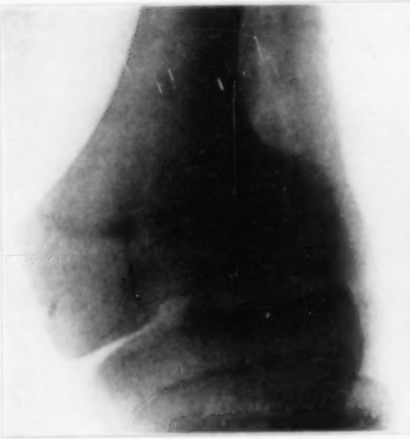

FIG. 1-A

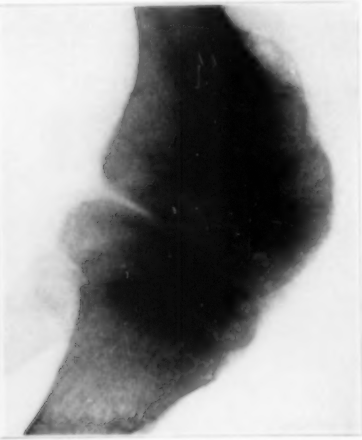

FIG. 1-B

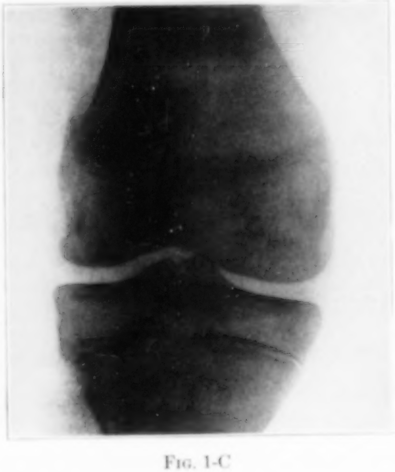

FIG. 1-C

Fig. 1-A: Case 1. December 14, 1945. Anteroposterior view of the left knee showed fragmentation and the early arrest of growth in the lateral epiphysis with valgus deformity.

Fig. 1-B: Lateral view of the left knee showed marked bony irregularity and destruction.

Fig. 1-C: Anteroposterior view of the right knee, taken at the same time, showed synovial thickening and early changes of the lateral femoral condyle.

about a third of the medial femoral condyle; these had not been apparent on the roentgenograms. The fragments were removed, the edges were trimmed down, and the panus was shaved off.

On January 5, 1946, an attempt was made to correct the valgus deformity of the left knee. The lateral femoral condyle was found to be entirely denuded of cartilage except for a loose fragment on the lateral aspect. There were multiple small cartilaginous bodies which had evidently become desiccated; some were loose in the joint, while others were adherent to the synovial membrane. These and all other loose fragments of cartilage were removed, and a cuneiform supracondylar femoral osteotomy with fixation by means of screws and a Vitallium plate was performed.

After the patient's dismissal on March 22, he was able to walk distances up to one mile without pain, swelling, or discomfort. He wore a brace on the left leg, but he felt that he could get along without it. He returned for a routine examination four months later. Because his younger brother, who was seen first at the Clinic at this time, began to have a similar disturbance of his femoral condyles, further studies were recommended for Case 1. Roentgenograms of the left knee showed it to be greatly distorted. Union, however, was shown to be solid and the alignment and position were good. Erosion of the tibial surface of the joint and of the femoral condyles had increased. The right knee exhibited good function with no increase in the valgus deformity.

The concentrations of alkaline and acid phosphatase were 9.6 and 3.3 King-Armstrong units, respectively. The concentration of calcium was 9.8 milligrams and of phosphorus 4.4 milligrams per 100 cubic centimeters of serum. The sedimentation rate (Westergren method) was 37 millimeters in the first hour. This moderate elevation is unexplainable. Careful study did not reveal anything suggestive of disease of the endocrine or central nervous systems.

The patient returned again on February 17, 1947. He had not had pain in either knee, but he had noticed swelling of both knees, which increased on activity. He continued to wear a brace on the left leg. Roentgenograms at this time showed evidence of further destruction of the tibial and femoral surfaces of the left knee

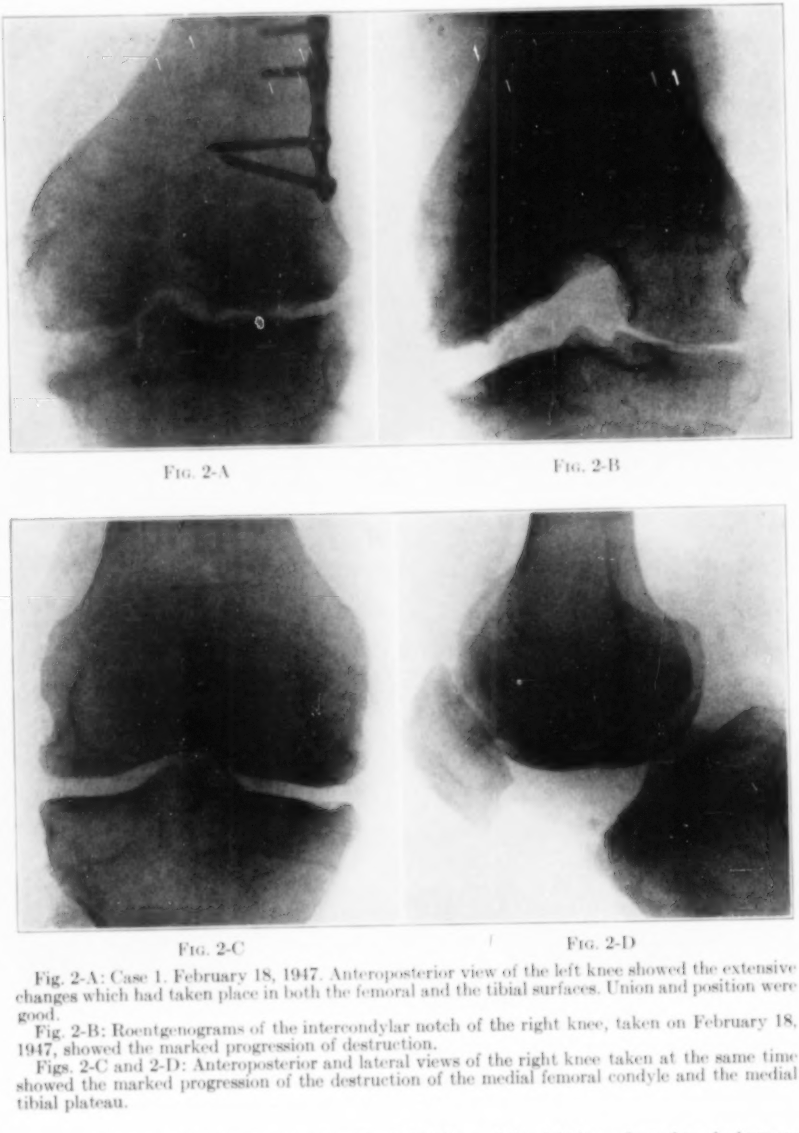

FIG. 2-A

FIG. 2-B

FIG. 2-C

FIG. 2-D

Fig. 2-A: Case 1. February 18, 1947. Anteroposterior view of the left knee showed the extensive changes which had taken place in both the femoral and the tibial surfaces. Union and position were good.

Fig. 2-B: Roentgenograms of the intercondylar notch of the right knee, taken on February 18, 1947, showed the marked progression of destruction.

Figs. 2-C and 2-D: Anteroposterior and lateral views of the right knee taken at the same time showed the marked progression of the destruction of the medial femoral condyle and the medial tibial plateau.

with numerous loose osteocartilaginous bodies (Fig. 2-A). Those of the right knee showed marked progression of destruction of the medial femoral condyle and medial tibial plateau (Figs. 2-B, 2-C, and 2-D).

For diagnostic purposes, fluid was aspirated from the right knee, which appeared to be somewhat bloody. A culture was negative for tuberculosis. The sugar content was 90 milligrams per 100 cubic centimeters; results of the direct test for bilirubin were negative, and the results of the indirect test were 1.9 milligrams per 100 cubic centimeters of serum. The protein measured 3.9 milligrams per 100 cubic centimeters, and the albumin-globulin ratio was 2.12 to 1. An attempt was made to aspirate fluid from the left knee, but sufficient fluid was not present.

The only addition to the treatment at this visit was the application of a long jointed brace to the right leg, which the patient was told to wear for any extended walking. The patient was seen on September 12, 1947, and again on April 8, 1948. At the latter examination the destructive process in the left knee had progressed to the point where there remained little joint space. He had remarkable motion and some instability;

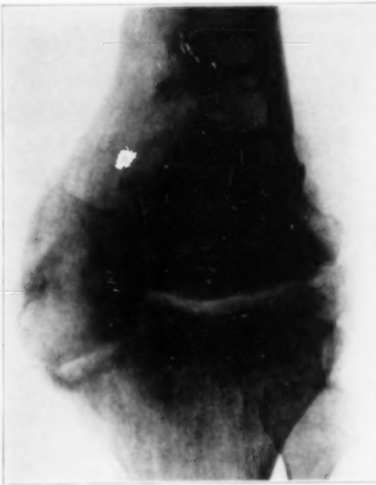

FIG. 3-A

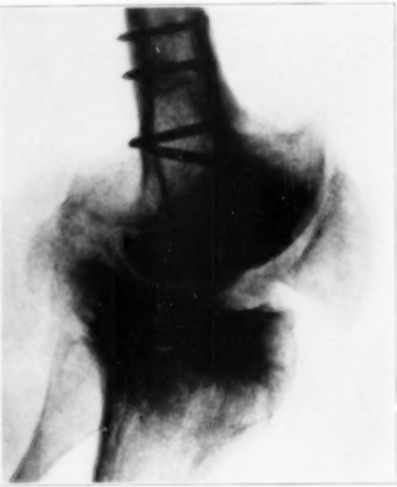

FIG. 3-B

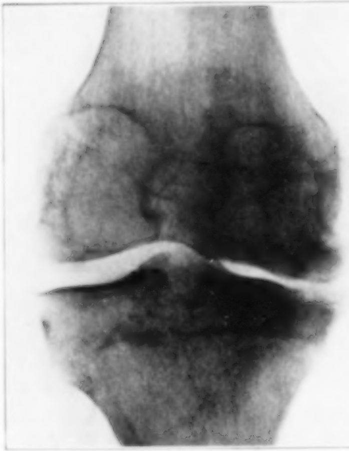

FIG. 3-C

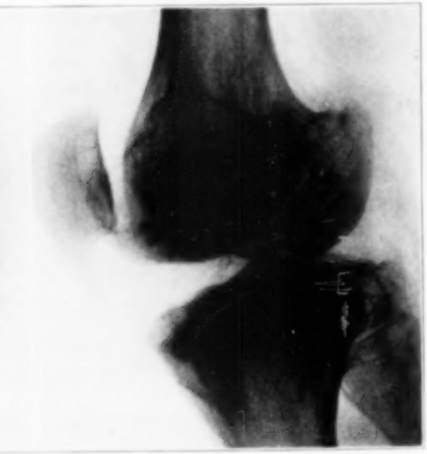

FIG. 3-D

Fig. 3-A: Case 1. March 9, 1949. Anteroposterior view of the left knee showed that there is some increase in the destructive change. Alignment of the leg, however, has been maintained.

Fig. 3-B: Lateral view of the left knee showed greatly distorted femoral condyles.

Figs. 3-C and 3-D: Anteroposterior and lateral views of the right knee showed stabilization of the destructive process.

he denied the existence of pain. The destructive process in the right knee seemed to have reached a standstill, and functionally this knee was a good one, without pain. The use of braces on both knees was continued.

The patient was last seen on March 9, 1949. He had been doing well with the long jointed braces. The stability and the power of the muscles of the right knee were good with a satisfactory range of motion present to almost complete flexion and extension. There was improved power in initiating extension in the left knee; full active extension was possible beyond the mid-range of motion. Lateral instability of the joint was marked, but the patient was able to walk well without pain. Some evidence of the progression of the lesion of the tibial plateau in the left knee (Figs. 3-A and 3-B) was demonstrable in the roentgenograms whereas further change in the right knee (Figs. 3-C and 3-D) was not apparent. The patient was advised to continue to wear his braces.

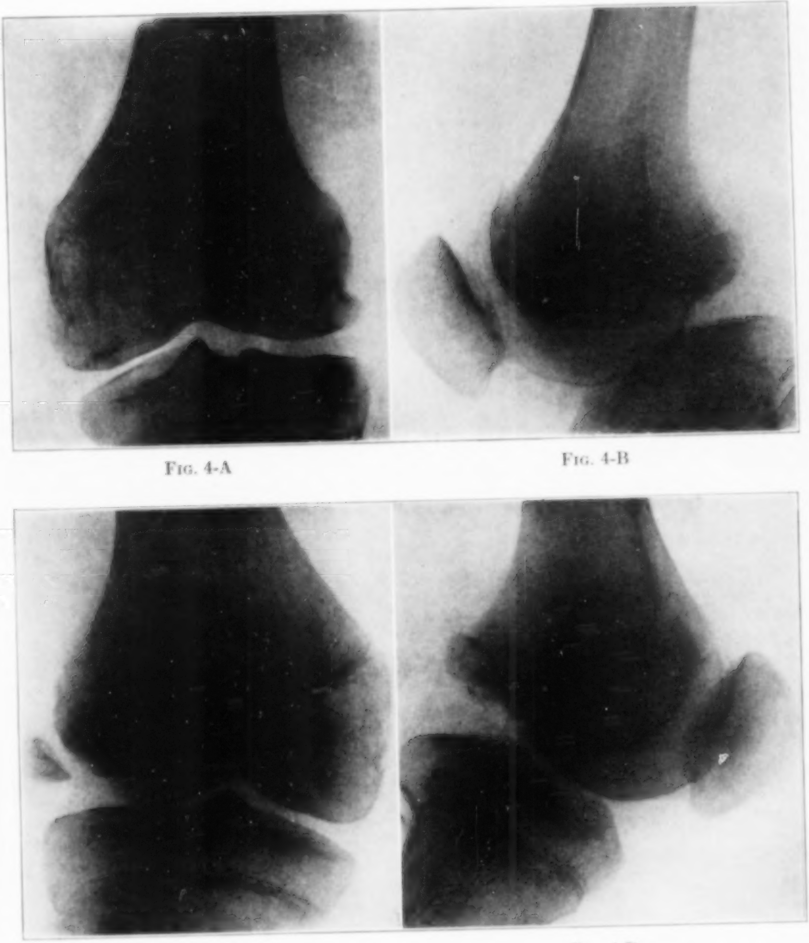

Fig. 4-A

Fig. 4-B

Fig. 4-C

Fig. 4-D

Figs. 4-A and 4-B: Case 2. July 29, 1946. Anteroposterior and lateral views of the left knee showed fragmentation of the lateral femoral condyle and valgus deformity.

Figs. 4-C and 4-D: Anteroposterior and lateral views of the right knee. Note the fragmentation of the lateral femoral condyle and the valgus deformity.

Case 2. A younger brother of the patient, Case 1, was first seen at the Clinic in July 1946, when he was fourteen years of age. In the spring of 1945, he had had acute tonsillitis. After the infection had subsided, it was noticed that he had a slight limp. In August 1945, tonsillectomy had been performed and in January of the next year the deformity of his legs had first been noticed. Since April 1946, his knees had become progressively larger. Pain, however, had not been present. As had been true of his brother, there was no history of redness, fever, or chills, and there had been no drainage.

Results in all other aspects of the physical examination were negative with the exception of those pertaining to the lower extremities. The circumference of the left thigh and calf exceeded that of the right by one-half and three-quarters of an inch (1.27 and 1.91 centimeters), respectively. The knees were markedly enlarged and there was valgus deformity of approximately 20 degrees. There was a full range of motion and slight crepitus bilaterally. Effusion and marked synovial thickening were present. Results of complete neurological examination were negative.

The urine, the erythrocyte, leukocyte and differential blood counts, the concentration of hemoglobin, the calcium and phosphorus content of the blood and the spinal fluid were within normal limits. Results of

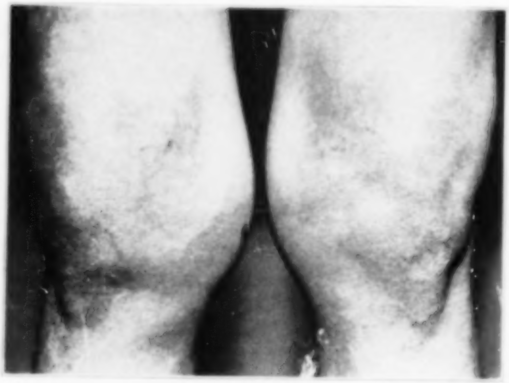
FIG. 5

Fig. 5: Case 2. February 18, 1947. Note the marked swelling of both knees and the valgus deformity.

Fig. 6-A: Case 2. February 22, 1947. The synovial membrane has been exposed but kept intact. Note both the distension and thickening.

Fig. 6-B: Through the opened and thickened synovial membrane the marked erosion and fragmentation of the lateral femoral condyle may be seen.

Fig. 6-C: The synovial membrane has been removed and the roughened bone surfaces have been trimmed.

Fig. 6-D: February 24, 1947. Specimens of the synovial membrane and the loose osteocartilaginous bodies from both knees are shown.

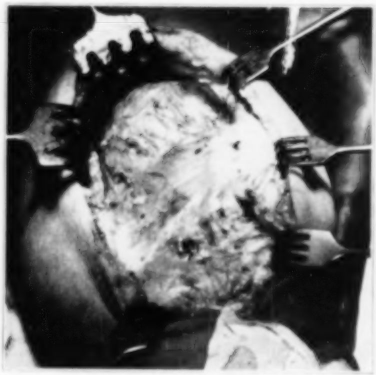
FIG. 6-A

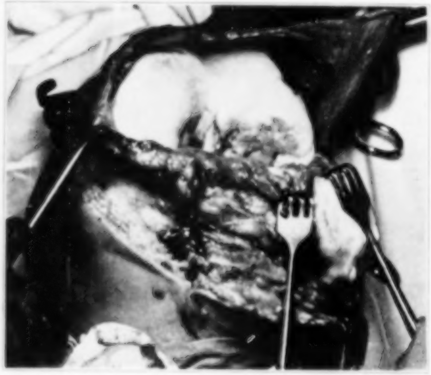
FIG. 6-B

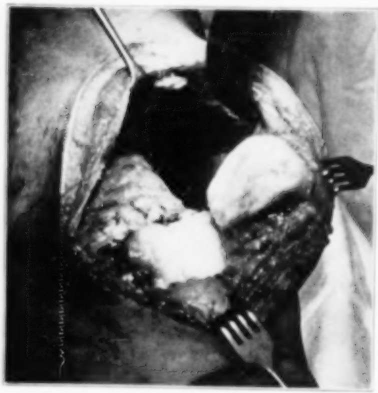
FIG. 6-C

tests for syphilis were negative; the alkaline phosphatase measured 7.2 King-Armstrong units; and 9.9 milligrams of 17-ketosteroids were excreted in the urine in twenty-four hours.

Roentgenograms exhibited evidence of a fragmentation of the lateral femoral condyle bilaterally with one large displaced fragment on the right (Figs. 4-A through 4-D).

The patient was not having sufficient trouble to justify surgical intervention, and he was advised to return in February 1947. During the interval of six months the swelling of both knees had progressed (Fig. 5), but he had not had pain. He had been wearing long braces on both extremities, and genu valgum had continued to develop with marked synovial thickening and effusion into the joints. Roentgenograms continued to show further evidence of destruction of the femoral condyles of both knees.

On February 22, bilateral aspiration and then synovectomy were done with removal of loose osteocartilaginous bodies from the left knee (Figs. 6-A through 6-D). Results of the analyses of the fluid from both knees are shown in Table I. The synovial membrane was thickened bilaterally and patches of hypertrophic villi had formed. Microscopically, the tissue exhibited evidence of slight inflammation with marked villous formation and islets of heterotopic cartilage. Plaster splints were applied postoperatively and were removed on March 8.

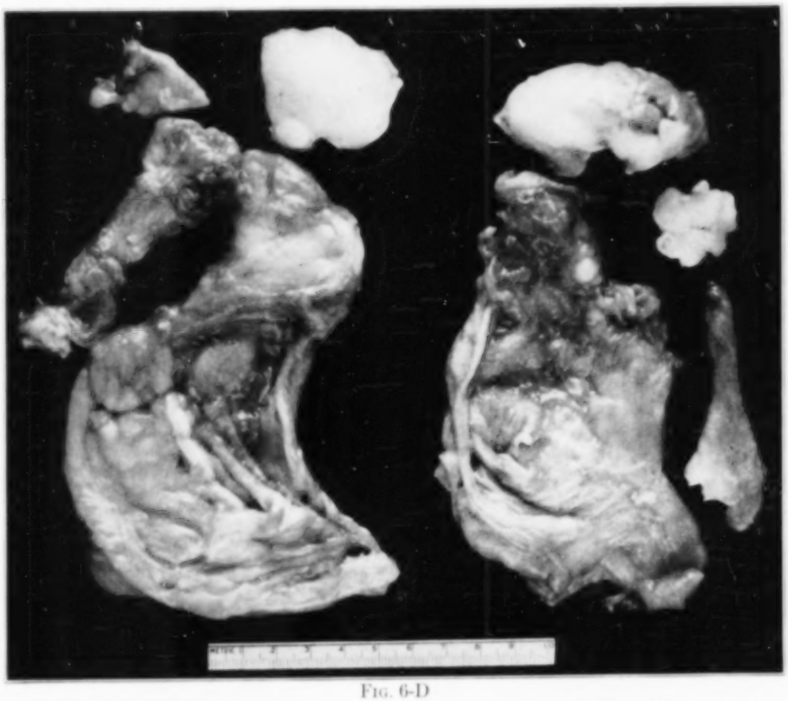

FIG. 6-D

The patient returned in September 1947. He was walking without a limp with both limbs in braces. He had 110 degrees of motion in both knees. It was the opinion of the authors from an inspection of the roentgenograms that the degeneration had not stopped. There appeared, however, to be some evidence of reorganization of the margins of the femoral condyles. Pain was denied. By April 8, 1948, the process in the left knee seemed to have become stabilized and further treatment for this knee was not advised. There had been enough destruction of the lateral femoral condyle of the right knee to recommend that osteotomy be performed in an attempt to correct the valgus deformity. This was accomplished in the supracondylar region on May 27, and the fragments were held with a Blount plate. Union took place in the usual time.

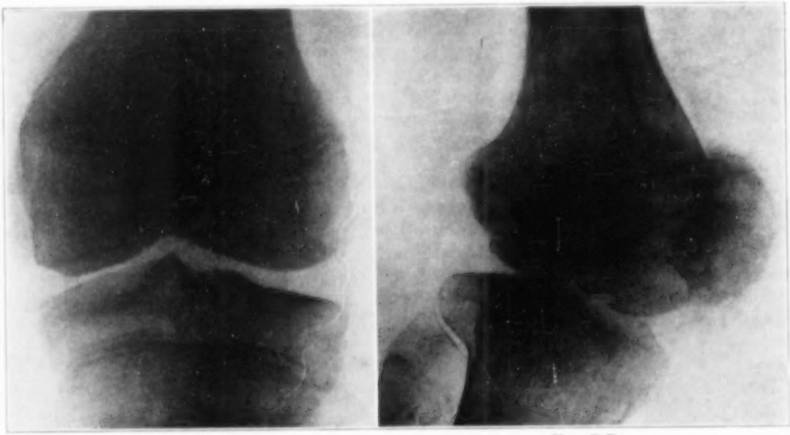

FIG. 7-A FIG. 7-B

Figs. 7-A and 7-B: Case 2. March 9, 1949. There seemed to be no increase in destruction.

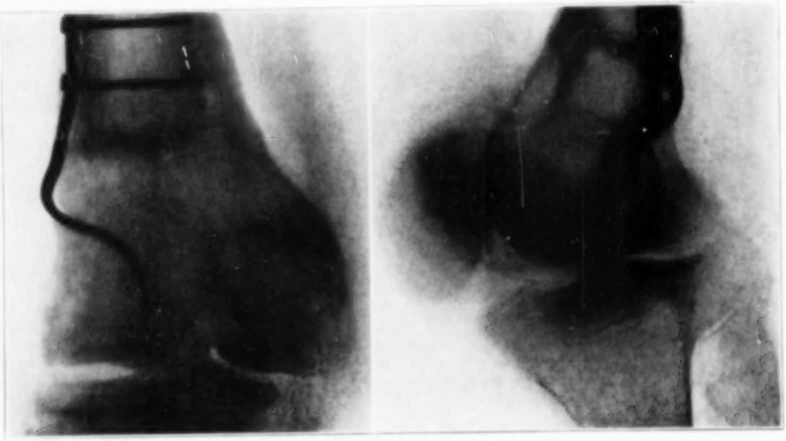

FIG. 7-C FIG. 7-D

Figs. 7-C and 7-D: Anteroposterior and lateral views taken of the right knee showed postoperative correction of the valgus deformity with union after fixation by means of a Blount plate. There appeared to be stabilization of the destructive process.

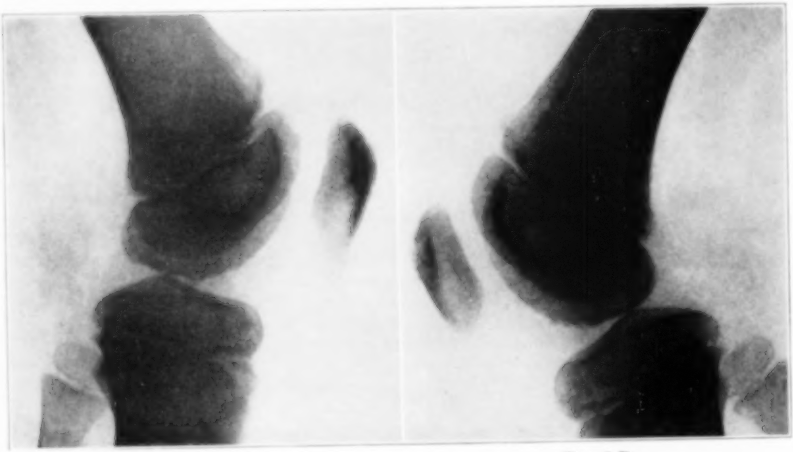

FIG. 8-A FIG. 8-B

Figs. 8-A and 8-B: May 11, 1949. Lateral views of both knees (Fig. 8-A, left; Fig. 8-B, right) of the third brother under observation showed irregularities of the femoral condyles.

The patient, when last seen on March 9, 1949, twenty-four months after the operation on the left knee and nine months after the operation on the right knee, had good stability of both knees. Both were enlarged. There was slightly more limitation of flexion of the right knee than of the left. The right knee was, however, capable of a greater degree of hyperextension. The function of both knees was good and there was no pain. A comparison of the roentgenograms with those previously taken did not reveal progression of the disease (Figs. 7-A through 7-D). The patient was advised to discontinue the use of braces in the house, but to continue with them for all out-of-doors activity.

COMMENT

While it is difficult to say whether or not the entity described should be called "osteochondritis dissecans", "chondromalacia of the knee joint", or "chondrodystrophy of the knee joint", it is certain that some pathological process was developing which prohibited the cartilage on the femoral condyles of these boys from maturing in normal fashion. Operations on the knees of these two boys disclosed the fact that nearly the whole cartilaginous surface of the lateral femoral condyle was loose, including some of the subchondral bone. This subchondral bone was granular and the defect extended deep into the femoral condyles. It is rare in osteochondritis dissecans of the knees to have such great defects that osteotomy of the femur is necessary to correct the valgus deformity. It is rare also to find knees in which such destruction has occurred, which are as painless as those of these two lads. The lack of a significant degree of pain and the extent of destruction of the femoral condyles might indicate neuropathic or Charcot's joint. However, on neurological examination, and even on analysis of the spinal fluid, we were unable to make the diagnosis of a neuropathic joint in either case. Histological studies of the synovial membranes were suggestive of rheumatoid arthritis, accompanied by villous synovitis and inflammation of fibrous tissue. This, however, is also consistent with traumatic synovitis.

It is unusual that the condition was bilateral and that it occurred in two brothers; it is with great interest that we watch the third brother, for we are now somewhat suspicious that in him the same process is in its incipient stage. The two older boys, who are strapping lads over six feet tall, are condemned to rather sedentary lives because of their knees. In the case of the third boy, serial roentgenograms for a period of five and one-half years, from the time the boy was four and one-half to nine years old, seem to indicate, however, that the same condition is developing, even though he has no symptoms (Figs. 8-A and 8-B).

OSTEOCHONDRITIS DISSECANS WITH SPONTANEOUS HEALING

BY ROBERT E. VAN DEMARK, M.D., SIOUX FALLS, SOUTH DAKOTA

In certain [1] of the outstanding current textbooks of orthopaedic surgery, it is stated that watchful waiting until the undisplaced fragment in osteochondritis dissecans is extruded into the joint is neither necessary nor desirable. This statement is generally true for adults, notwithstanding the fact that revascularization of the undisplaced fragment has long been known.[3,4] For growing children, surgery is frequently unnecessary, as is illustrated in the following cases in which normal knees were obtained through conservative treatment and were demonstrated on clinical and roentgenographic examination.

CASE 1. D. E. J. A white male, eleven years of age, was seen on January 23, 1947, because of intermittent pain in the left knee. The pain occurred on twisting or turning the knee and lasted for two to twelve hours, during which period the patient limped. There was no history of local injury, redness, or swelling; the condition had gradually appeared two years previously. Clinical examination of the affected knee was essentially negative except for slight infrapatellar fullness. Roentgenograms (Fig. 1-A) showed the typical cystlike formation first postulated by Wolbach and Allison to precede the formation of loose bodies. The patient was placed on crutches and was not permitted weight-bearing. Subsequent roentgenograms (Figs. 1-B, 1-C, and 1-D) showed the typical osteochondritis dissecans formation with gradual revascularization. Weight-bearing was resumed on December 6, 1947. When last seen in March, 1948, the patient had no complaints, and the knee was normal, both in appearance and in range of motion.

CASE 2. J. R. A white male, thirteen years of age, was first seen on January 30, 1950. He gave a history of intermittent pain and swelling in the right knee for a period of three years. The pain was so severe that it caused a marked limp. Clinical examination revealed tenderness over the anteromedial aspect of the flexed joint, and roentgenographic examination demonstrated the presence of a typical osteochondritis dissecans fragment over the lateral aspect of the medial femoral condyle (Fig. 2-A). The patient was placed on crutches and was not allowed weight-bearing. On February 1, 1950, a plaster cylinder was applied, extending from the upper portion of the thigh to the ankle. The knee was thus immobilized until July 5, 1950, at which

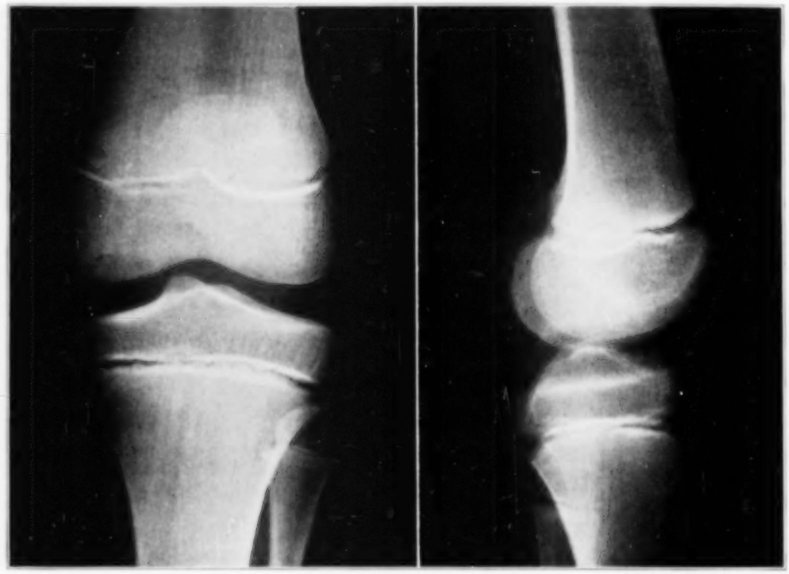

Fig. 1-A

Case 1. D. E. J. January 23, 1947. White male, eleven years of age. Note cyst in medial femoral condyle.

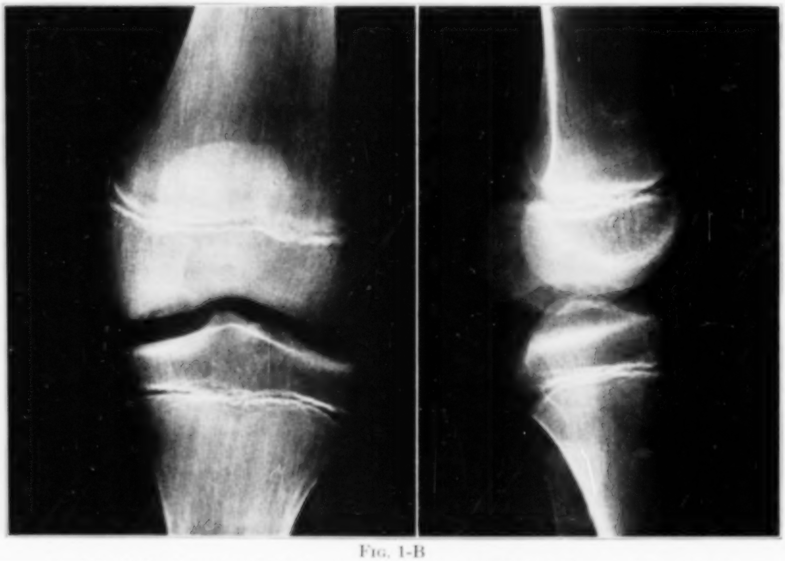

Fig. 1-B

April 19, 1947. Osteochondritis dissecans is seen in both views in the roentgenograms.

time motion was begun. Weight-bearing was still not allowed. Partial weight-bearing, however, was permitted on September 27, 1950. Several roentgenograms (Figs. 2-B through 2-E) demonstrated the gradual revascularization of the fragment. When the patient was last seen on December 6, 1950, the knee appeared to be entirely normal both clinically and as shown by roentgenograms.

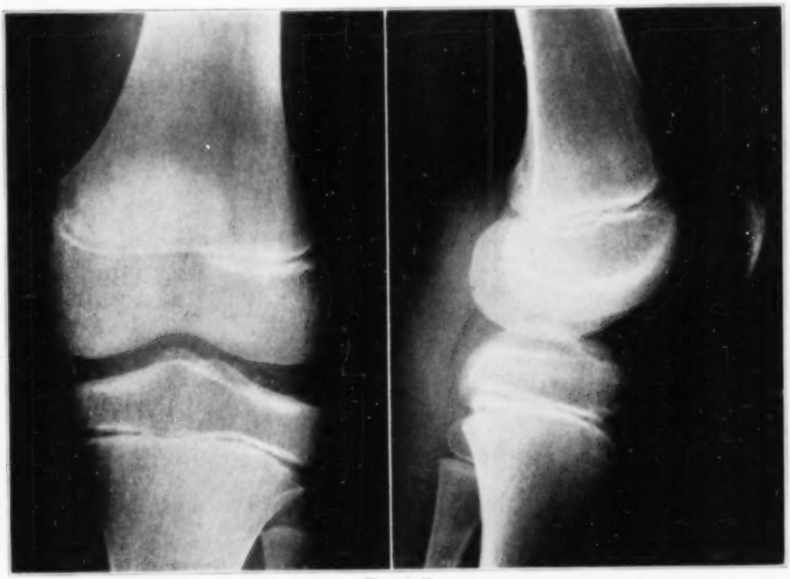

Fig. 1-C

August 12, 1947. A more normal appearance is seen in the roentgenograms, following treatment in which weight-bearing was not permitted.

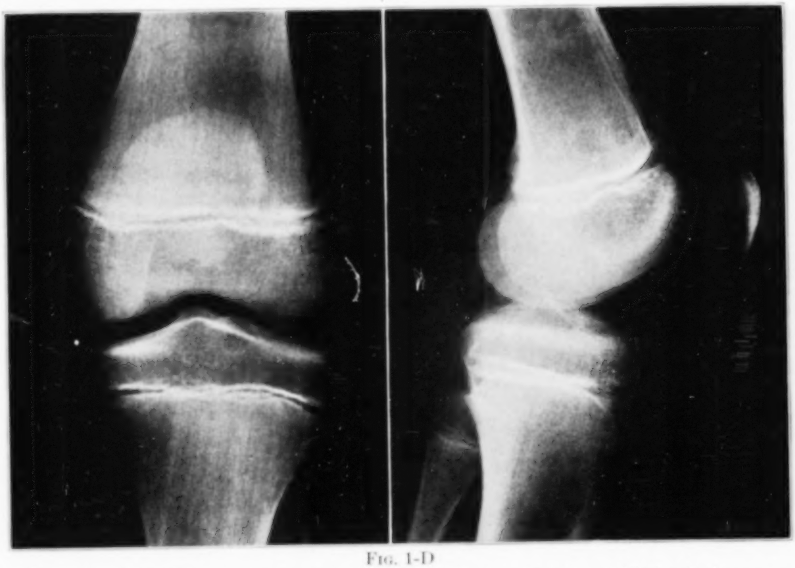

Fig. 1-D

December 6, 1947. Roentgenograms taken at the completion of treatment. Patient had no complaints and the knee was clinically normal.

DISCUSSION

Although complete [5] and partial [2] revascularization of the fragment in osteochondritis dissecans in children has been reported in the recent American literature, little reference is made to the six cases reported in children by Wiberg, [6,7] in which healing

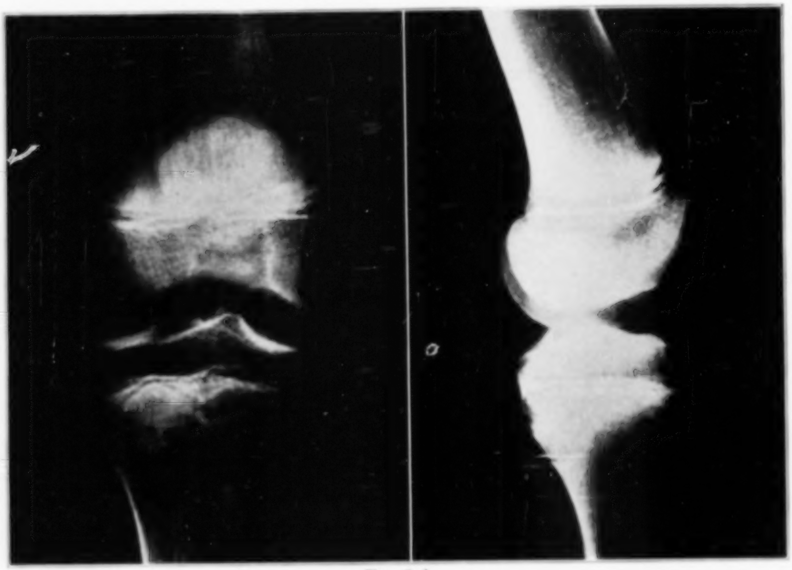

Fig. 2-A

Case 2, J. R. January 30, 1950. White male, thirteen years of age. Osteochondritis dissecans is seen in roentgenograms.

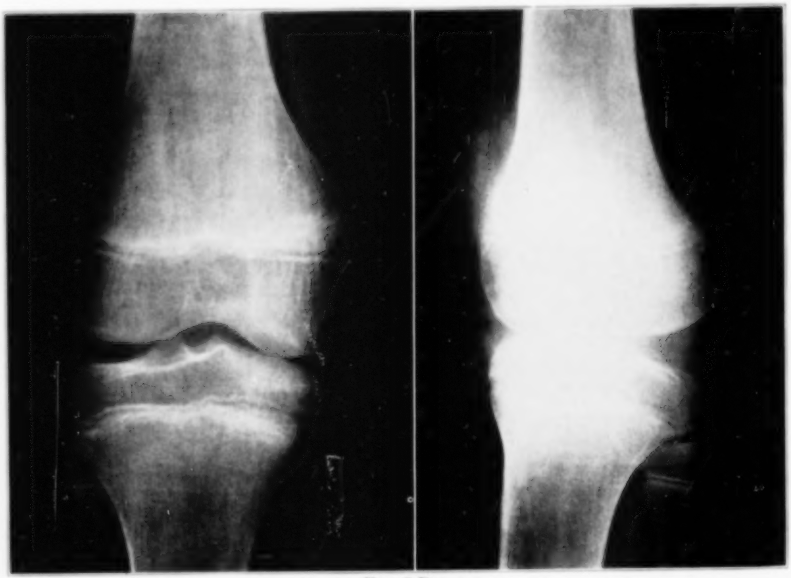

Fig. 2-B

May 24, 1950. Roentgenograms of same patient following almost four months of treatment in which weight-bearing was not allowed and the knee was immobilized in a plaster cylinder.

occurred spontaneously. It was Wiberg's conclusion that the process is not likely to heal after the age of twenty years in any case, perhaps not after sixteen or seventeen years. He

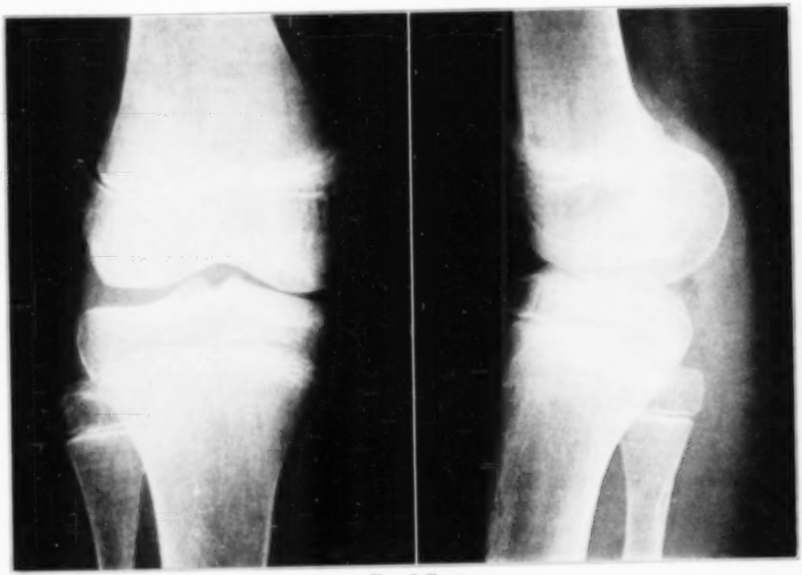

FIG. 2-C

July 5, 1950. Continued improvement is shown in roentgenograms.

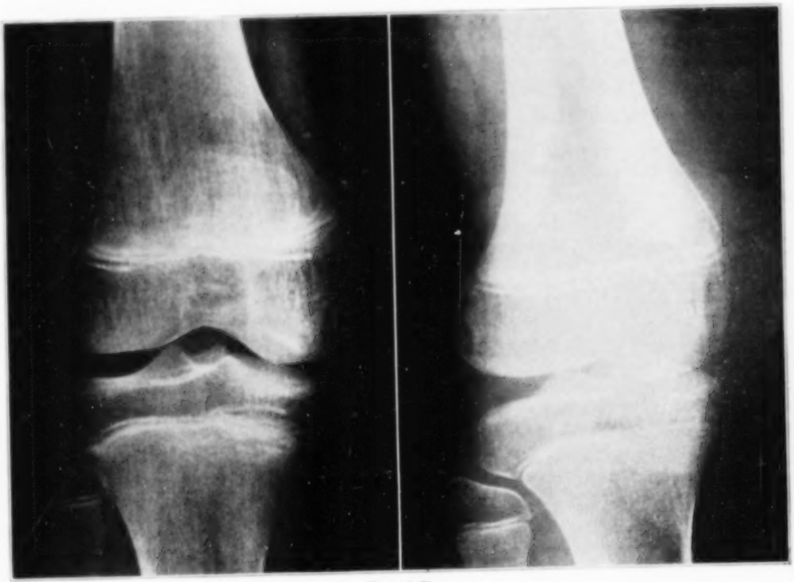

FIG. 2-D

August 9, 1950. Roentgenographic appearance of knee.

further stated that, if, in such cases under conservative treatment, the body becomes detached, it should be removed. He felt there is every reason to use conservative treatment in many cases and to operate after the age of twenty, or earlier only on definite indications.

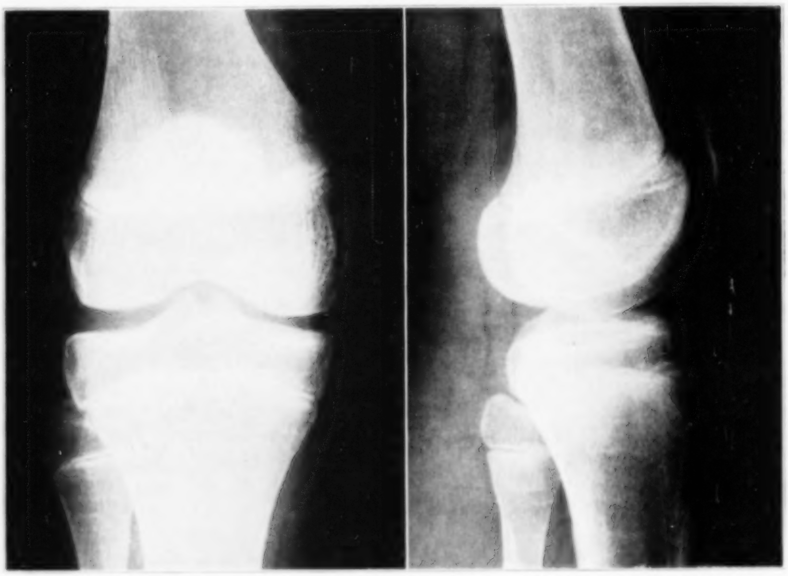

FIG. 2-E

December 6, 1950. Clinical findings were entirely normal.

CONCLUSION

As with Legg-Perthes disease, the revascularization of an undisplaced fragment in osteochondritis dissecans of the knee in children appears to proceed with reasonable rapidity in certain cases, providing the joint is protected from weight-bearing. The roentgenographic findings in the two cases herein reported suggest that, in children, treatment in which weight-bearing is not allowed should be adopted for a period of at least six months,—surgery being reserved only for those cases in which clinical and roentgenographic improvement cannot be demonstrated or in which displacement occurs.

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ACCESSORY SACRO-ILIAC ARTICULATIONS *

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From the Department of Anatomy, New York State College of Medicine, Syracuse

Accessory sacro-iliac joints have been recognized, but little has appeared in the literature relative to their clinical significance. An attempt to coordinate anatomical and roentgenographic findings with the symptomatology may serve to demonstrate the clinical importance of these vicarious articulations.

The antero-inferior portions of the adjacent surfaces of the sacrum and the innominate bone form the true ear-shaped sacro-iliac joint. Only about one half of these adjacent surfaces is actually in contact. The remaining portions, separated by a deep cleft one-eighth to one-quarter of an inch wide, are connected by the posterior sacro-iliac ligaments. However, articular facets may develop a bridge across this space and thus form accessory sacro-iliac joints. These are above, behind, and entirely separate from the true sacro-iliac joints. They are movable, diarthrodial articulations, with joint space, capsule, and articular surfaces (Fig. 12); in their normal condition they should be considered asymptomatic.

A group of anatomical specimens—185 half sacra and 163 ilia obtained from the Department of Anatomy, New York State College of Medicine—were dissected, and roent-

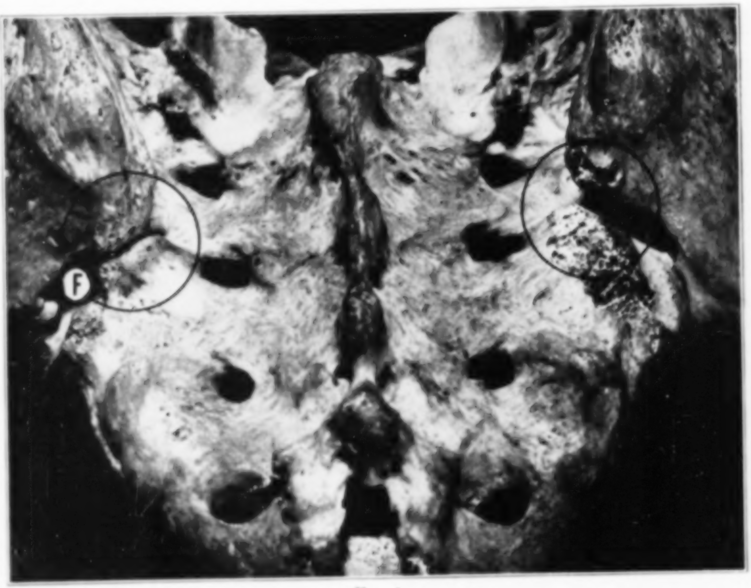

FIG. 1

Articulated specimen, showing bilateral superficial accessory sacro-iliac articulations. Facets on the posterior superior iliac spines articulate with corresponding facets on the sacrum. These, of the superficial type, are opposite the second posterior sacral foramina. The posterior surface of the facet on the right side has been removed, revealing the edge of the articular surface. The foramen for branches of the superior gluteal nerve and artery is clearly shown on the left side between the accessory and true sacro-iliac joints (*F*). The circles, as in all the illustrations, enclose the accessory sacro-iliac joints.

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* Based on exhibits at the Annual Meeting of the American Medical Association, San Francisco, California, June 1950, and at the American Roentgen Ray Society, St. Louis, Missouri, September 1950.

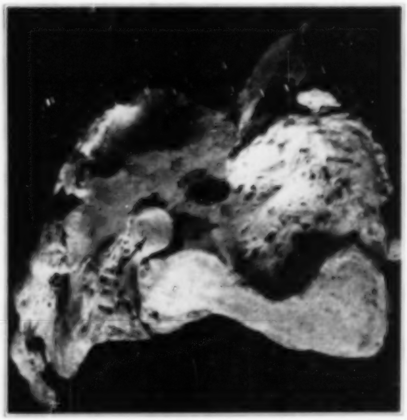

FIG. 2

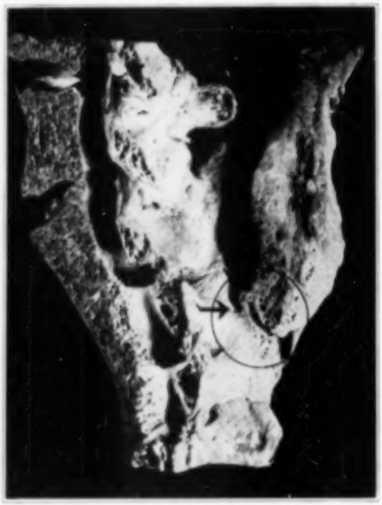

FIG. 3

Fig. 2: A sacrum viewed from the right side. Note the round facet for an accessory sacro-iliac articulation (arrow) above and behind the true, so-called auricular, sacro-iliac articulation. Note also the space between these articular surfaces for passage of the nerve and blood vessels. In all of the cases studied, the accessory and the true sacro-iliac joints were found to be separate.

Fig. 3: Specimen from male, aged fifty, showing superficial accessory sacro-iliac joint (arrow) with arthritic spur formation. The nutrient foramen shadow, foreshortened, is seen to the right of and below the accessory joint.

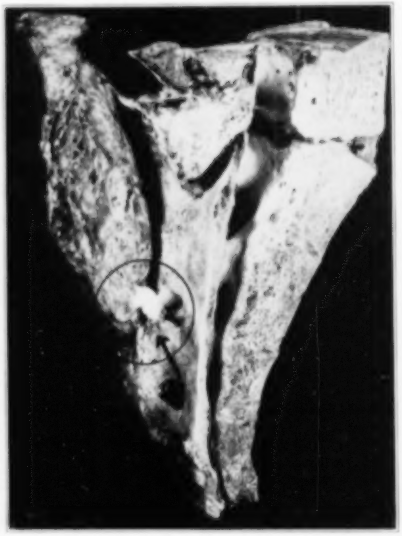

FIG. 4

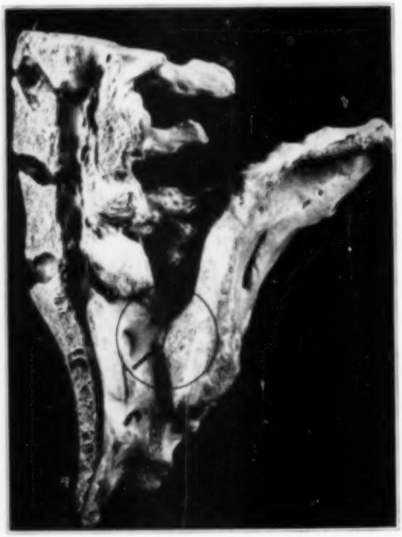

FIG. 5

Fig. 4: Half sacrum from a male, aged seventy-four years, showing ankylosed superficial accessory sacro-iliac articulation (arrow) opposite second posterior sacral foramen. The normal cleft between the iliac crest and the posterior surface of the sacrum can be seen above this bridged joint.

Fig. 5: Specimen from a male, seventy-five years old. Deep type of accessory sacro-iliac articulation is seen opposite the first posterior sacral foramen. The usual cleft between the ilium and posterior surface of the sacrum is bridged by this vicarious articulation (arrow). The articulation is separated from the true sacro-iliac by a passage for the nerve and blood vessels. There is no connection between this joint and the old fractures of the third and fourth vertebral bodies and the right ilium, which occurred twenty-five years before death.

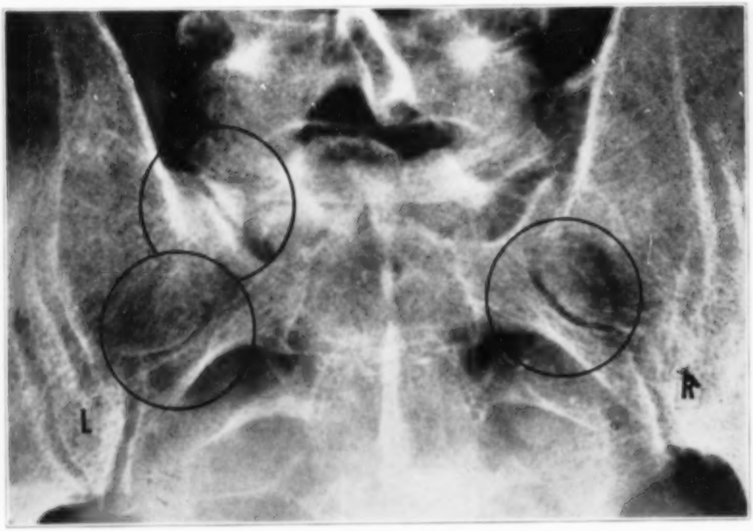

Fig. 6

Roentgenogram of male, sixty-two years old, with sacro-iliac pain and sciatica on the left. Patient complained of a "catch" on this side upon straight-leg raising. The roentgenogram shows a deep accessory joint with arthritic changes, i.e., irregularity of the articular surface and eburnation of the underlying bone (upper circle). The patient also has bilateral superficial accessory sacro-iliac articulations without arthritic changes (lower circles).

The letters R and L in each case appear over the lower posterior portion of the true sacro-iliac joint. (See also Figs. 7, 8, 9, and 10.)

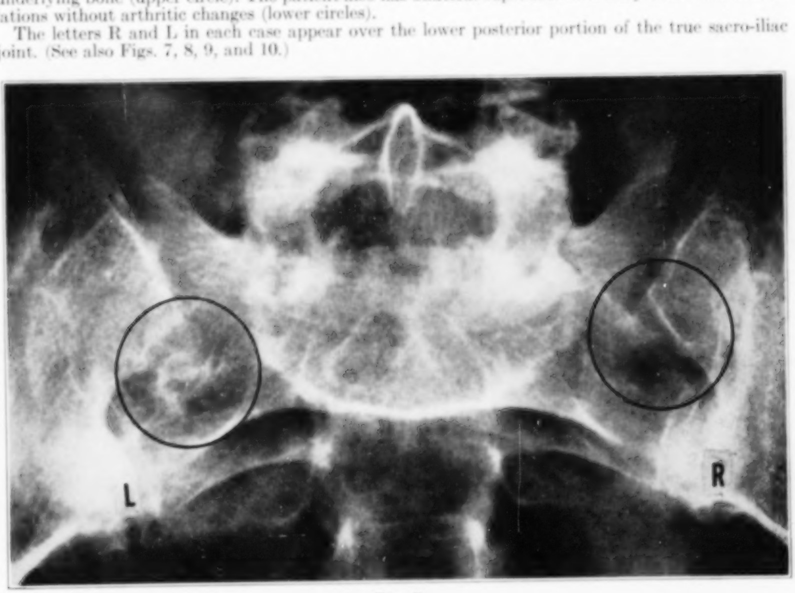

Fig. 7

X-ray of female, sixty years old, who had had pains in the low back and thighs for past three months. The film reveals a superficial accessory sacro-iliac on the left side with an arthritic spur projecting laterally into the adjacent nutrient foramen. (Compare with specimen shown in Fig. 3 in which, however, the spur is on the medial side of the joint.) The patient complained of tenderness to deep pressure over the posterior superior iliac spine on the left side. There is also an accessory joint on the right side which shows little evidence of arthritic change. The patient was originally examined in March 1943. When interviewed seven and a half years later she still had some low-back pain, but only after heavy lifting.

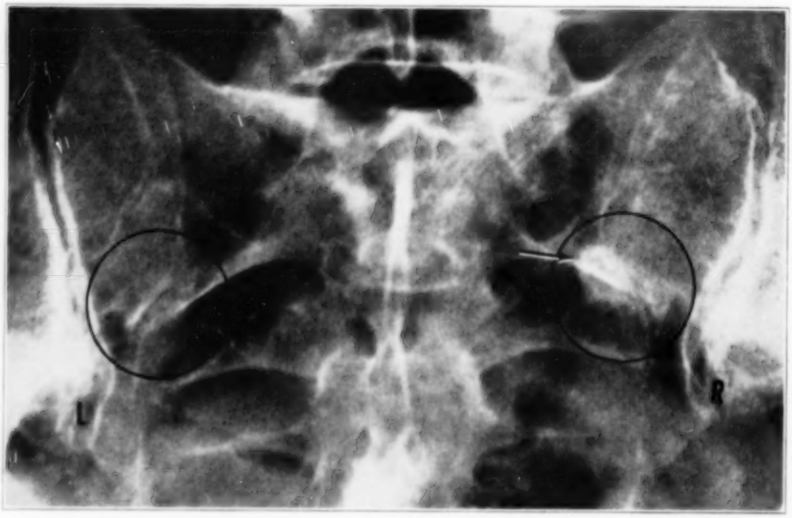

Fig. 8

Roentgenogram of female, forty-six years old. Bilateral superficial arthritic accessory sacro-iliacs; on the right side there is a spur projecting from the medial side of this arthritic joint (arrow). The foramen landmark can be seen just within the circle on the left side.

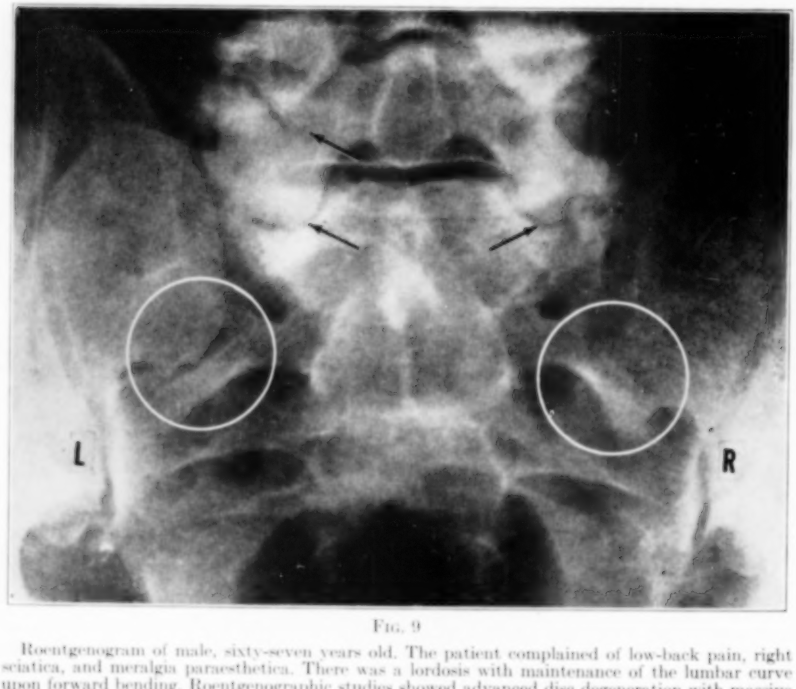

Fig. 9

Roentgenogram of male, sixty-seven years old. The patient complained of low-back pain, right sciatica, and meralgia paraesthetica. There was a lordosis with maintenance of the lumbar curve upon forward bending. Roentgenographic studies showed advanced disc degeneration with massive spur formation. As a result of the lordosis and disc thinning, there is telescoping of the posterior articulations, with impingement of the tips of the inferior articular processes against the subjacent neural arches. Notching and eburnation, with development of arthritic changes, have occurred at

(*Continued on p. 153*)

FIG. 9.—(*Continued from p. 152*)
these points of impingement (arrows). The intervertebral foramina have been encroached upon. These changes were compatible with the patient's symptoms. The roentgenogram is shown here only as an example of ankylosed right accessory sacro-iliac. The left accessory joint appears essentially normal.

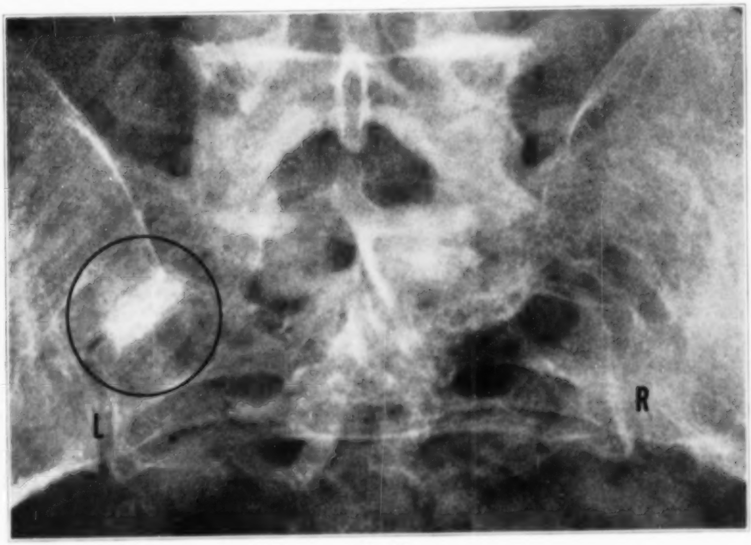

FIG. 10

Roentgenogram of female, sixty-six years old, who complained of low-back pain and sciatica on the left. The patient has a left superficial accessory sacro-iliac showing arthritic changes, that is, eburnation of the underlying bone. Note the foramen (close to edge of circle) between this joint and the true sacro-iliac. The patient complained bitterly of pain upon deep pressure over this abnormal articulation. The plane of this joint forms an angle of nearly 60 degrees with that of the true sacro-iliac.

genograms of these specimens were compared with those of 200 consecutive private patients. Two types of accessory sacro-iliac articulations were identified. The more common superficial accessory sacro-iliac joint is seen between the posterior superior iliac spine and the lateral crest of the sacrum, opposite the second posterior sacral foramen. Prominent facets surmounted by articular cartilage develop at these points. The superficial joint is very close to the body surface and, if arthritic, it may be tender to deep pressure. It is separated from the true sacro-iliac joint by a foramen through which pass branches of the superior gluteal nerve and artery. This foramen constitutes a useful landmark for identifying the superficial accessory sacro-iliac articulation. It lies between that vicarious joint and the true sacro-iliac joint.

The deep articulation, less frequently found, develops between the large roughened tuberosity of the ilium and the smaller sacral tuberosity. It is found opposite the first posterior sacral foramen.

The deep and superficial types may occur together in the same individual. Occasionally, the two types become fused to form a large accessory sacro-iliac, entirely separate from the true joint. This may encompass the sacral tuberosity and the crest of the sacrum down to the second posterior foramen. Articulation for an enlarged fifth transverse process occasionally simulates the appearance of a third articulation, such as that reported by Giraudi.

The planes of the normal and the accessory articulations may form an angle amounting to as much as 60 degrees. The resultant sheering stress constitutes a mechanical hindrance to the customary movements between the ilium and the sacrum. This may contribute in part to the arthritic changes so frequently noted. Complete bony ankylosis

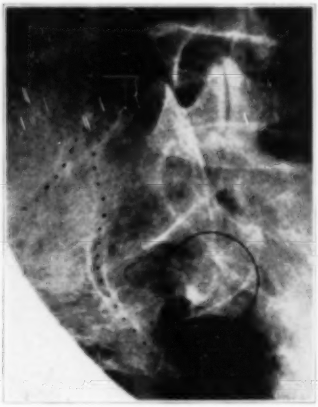

FIG. 11

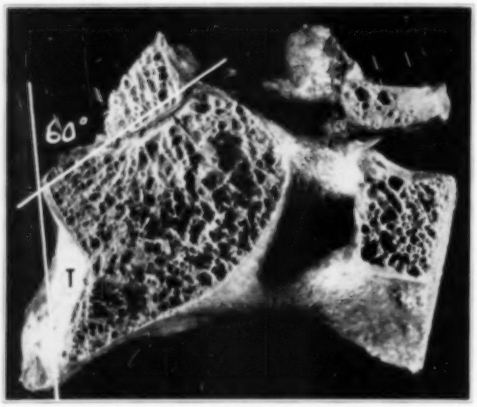

FIG. 12

Fig. 11: Roentgenogram of female, aged sixty years. The patient had felt sudden sharp pain in low back upon leaning forward five weeks before examination; there was no history of injury. She indicated the left posterior superior iliac spine as tender to deep pressure. The 45-degree oblique roentgenogram shows an arthritic left accessory sacro-iliac. Note that this is entirely separated from the true sacro-iliac (dotted line) by the tunnel for passage of the nerves and blood bessels. The postero-anterior and anteroposterior views usually show the condition better than the oblique studies.

Fig. 12: Transverse section through the left half of a sacrum at its first foramen. The plane of the true sacro-iliac articulation (*T*) forms an angle of 60 degrees with the plane of the accessory joint. This would seem to constitute a mechanical disadvantage to the normal movements of the true sacro-iliac joint. Note the cartilaginous articular surfaces, the joint space, and the capsule of this vicarious articulation (arrow).

has also been observed. Patients with accessory articulations frequently complain of low-back pain, sciatica, muscle spasm, limitation of motion, or tenderness to deep pressure over the accessory joint.

Peterson, in 1905, and Derry, in 1911, reported on the incidence of accessory articulations in sixty-three and 192 specimens respectively. The incidence in Peterson's series was 16 per cent., in Derry's 10.4 per cent. Trotter, in a study of 958 anatomical specimens, found an incidence of 36 per cent. Her findings "supported the belief that the . . . articular facets are covered by hyaline cartilage and separated by an articular cavity and that the joint is surrounded by a capsule". She also stated that "the incidence of accessory articular facets was found to increase with increase in age".[5]

Study of the 185 specimens of half sacra revealed accessory sacro-iliac joints in 18 per cent. Of the 163 ilia examined, 16 per cent. revealed accessory articular facets.

No figures are available for asymptomatic individuals. In a review of 200 consecutive roentgenographic examinations of private patients, most of whom complained of low-back pain with or without sciatica, 33.5 per cent. of patients were found to have accessory sacro-iliac joints. In 42 per cent. of these patients the condition was bilateral. The superficial type occurred about four times as frequently as the deep. Of the total number of such vicarious joints, 64 per cent. showed no arthritic changes, 36 per cent. were obviously arthritic, and 6 per cent. were ankylosed. Roentgenographic changes considered as indicative of an arthritic process were thinning and irregularity of the joint space, bony exostoses of joint margins, and eburnation of the subjacent bone.

Roentgenograms may be made with the patient in either the prone or the supine position. Sometimes the best result is obtained in the axial or tangential position. For this, the patient sits on the end of the Bucky table, bent forward, with the central ray directed vertically downward toward the lumbosacral joint. A large sand bag placed against the prominence of the sacrum will lessen fogging from scattered radiation. Stereoscopic studies, preferably with a longitudinal shift, are essential.

SUMMARY

Accessory sacro-iliac joints frequently develop posteriorly between the ilium and the sacrum.

Both deep and superficial types have been observed. The latter occur more frequently and develop between the posterior superior iliac spine and the posterior surface of the sacrum.

These movable diarthrodial joints may become arthritic and even ankylosed.

They seem to be compatible with symptoms of low-back pain and sciatica.

NOTE: The author is indebted to Prof. Philip B. Armstrong of the Department of Anatomy, and to Miss Stella Zimmer of the Department of Photography, of the New York State College of Medicine, Syracuse, New York, for assistance in the preparation of this material.

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ANATOMICAL VARIATIONS IN THE ARTICULATION BETWEEN THE SECOND AND THIRD CERVICAL VERTEBRAE *

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A number of authors have called attention to changes in the cervical spine as a common cause for headaches and shoulder, chest, and arm pains. They have presented various theories as to the local causes of these, along with descriptions of the pathological changes taking place in the spine. Their reports were based entirely upon roentgenographic and clinical findings. One of the authors [7] reviewed these findings in a recent article.

More recently, Morton dissected twenty cadaver specimens of the cervical spine. He reported changes in the vertebral bodies, intervertebral discs, and the foramina, but he did not mention the variations in the apophyseal articular processes between the second and third cervical vertebrae.

Josey has presented a series of twenty cases of headache radiating to the occipital or frontal regions which was associated with soreness and stiffness in the upper portion of the neck. He found tenderness over the third cervical nerve as it emerges from the foramen in all cases. In most instances, pressure applied over the nerve at this point reproduced the headache. Roentgenograms revealed a loss of the normal flexion curve in the upper cervical spine in all, but showed degenerative arthritic changes in only two. However, he did not mention any anomalies or variations in the second and third cervical articulations.

Anatomical studies of the cervical spine reveal that the cervical vertebrae are different from those of the thoracic spine and the lumbar spine and that the differences involve

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* Material for this study was obtained through the courtesy of the Department of Anatomy, University of Colorado School of Medicine, Denver.

TABLE I

ANALYSIS OF EIGHTEEN SPECIMENS SHOWING VARIATIONS IN THE ARTICULAR FACETS BETWEEN THE SECOND AND THIRD CERVICAL VERTEBRAE

	Angles from Sagittal Plane (*Degrees*)			Inclination from Vertical Angle (*Degrees*)			Diameter (*Millimeters*)				Other Changes	
Specimen	Right	Left	Difference	Right	Left	Difference	Right	Left	Difference	Control*	Shape Irregularity	Degenerative
1	49	80	30	45	13	32	14	11	3	14		
2	70	59	11	39	40	1	12	12	0	15		
3	90	90	0	20	45	25	10	15	5	15	Left	Left
4	85	84	1	35	45	10	16	13	3	14		
5	73	39	34	45	40	5	15	15	0	16		
6	90	90	0	25	35	10	14	15	1	15		Bilateral
7	72	90	18	45	32	13	10	10	0	14		
8	90	90	0	60	46	14	15	11	4	14		
9	75	84	9	47	36	11	12	11	1	15		
10	20	90	70	55	50	5	11	17	6	16		Left
11	60	70	10	52	55	3	11	10	1	12		
12	80	82	2	35	25	10	13	12	1	15		
13	60	90	30	30	60	30	13	17	4	17		
14	30	60	30	45	80	35	12	10	2	15		
15	90	90	0	20	25	5	17	16	1	18		
16	75	64	11	40	30	10	14	10	4	15		
17	81	60	21	46	39	7	14	15	1	15		
18	90	82	8	61	56	5	20	12	8	17		Right

* Fourth cervical vertebra.

both the bodies and the apophyseal articular processes. Each of the vertebral bodies below the second cervical vertebra has an uncinate process on its superior lateral border bilaterally, which forms a concavity when viewed in the sagittal plane. The inferior surface of the adjacent vertebra is convex in the same plane (Fig. 1, *b*). Some anatomists have noted that the uncinate processes form separate joints and that these joints are lined with synovial membrane.

We were unable to demonstrate this finding in our dissection. This articulation is important, for it gives lateral stability to the cervical spine. The superior apophyseal

TABLE II

VARIATION BETWEEN THE ANGLES OF THE PLANES OF INCLINATION MADE BY THE RIGHT AND LEFT ASPECTS OF THE SECOND AND THIRD CERVICAL APOPHYSEAL JOINT

Variation (*Degrees*)	No. of Specimens	Per cent.
0–5	1	5.6
5–10	1	5.6
10–15	8	44.3
15–20	1	5.6
20–25	2	11.1
25–30	1	5.6
30–40	3	16.6
Over 40 (70)	1	5.6
Total	18	100.0

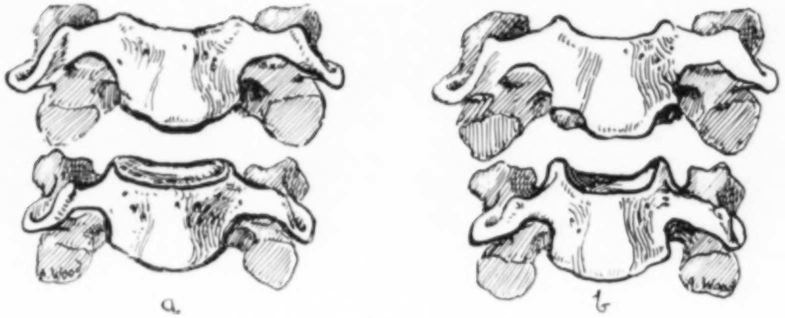

Fig. 1

Drawings from the specimens showing the uncinate processes of the bodies of the cervical vertebrae. They are absent in *a* and present in *b*.

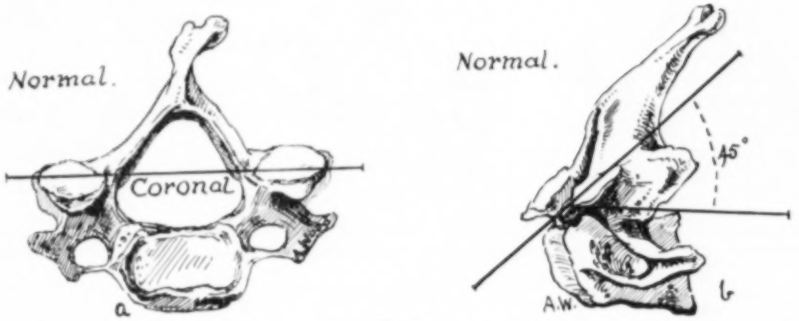

Fig. 2

Drawings to illustrate the normal plane and forward inclination of the apophyseal articular processes; *a* shows both of the processes in the coronal plane, while *b* is a semilateral view, showing the forward superior inclination of the processes.

articular processes are almost round, slightly oval, plates of bone which are fused inferiorly with the root of the lamina; and their articular surfaces are flat, face posteriorly, and are turned superiorly at an angle of 45 degrees. The inferior processes arise from the inferior side of the root of the lamina directly caudad to the superior ones; their articular surfaces are flat, the same shape as the superior processes, and face anteriorly and inferiorly at an angle of 45 degrees. The plane of the apophyseal joints formed by these processes is directly lateral, or 90 degrees, from the sagittal plane (Fig. 2, *a*), with an inclination superiorly and anteriorly of 45 degrees (Fig. 2, *b*). The structure of these joints is such that they give anterior and posterior stability to the cervical spine.

The anatomy of the cervical vertebrae as described allows free flexion, extension, and lateral motion, but it allows only slight rotation. Rotation takes place almost entirely in the first two cervical joints. Thus variations in the apophyseal articulations of any of the cervical vertebrae will produce irregular motion and, at times, a definite instability of the joint involved. The study of thirty-six cadaver specimens presented in this report indicates that these variations are not infrequent and that the variations were confined to articulations between the second and third cervical vertebrae. In two specimens, however, the third and fourth articulations were involved. None of the specimens showed any change in the articulations of the bodies, although in one museum specimen the uncinate processes between the second and third cervical vertebrae were absent (Fig. 1, *a*). Eighteen of the specimens showed insignificant changes. The planes, angles of inclination, and size of the apophyseal joints in this group were found to be fairly constant: The planes varied less

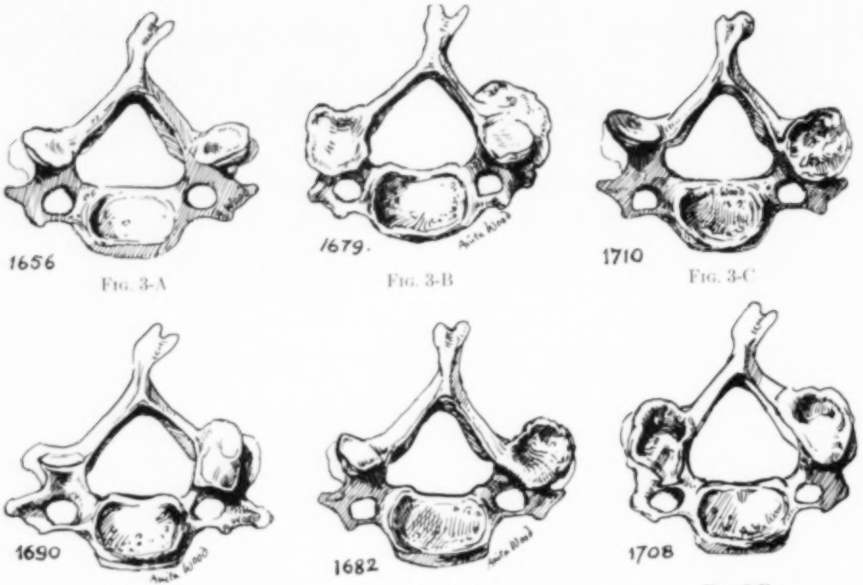

Fig. 3-A Fig. 3-B Fig. 3-C

Fig. 3-D Fig. 3-E Fig. 3-F

Drawings of specimens from superior view of the third cervical vertebrae show the variations in the planes, angles of inclination, size, and shape of superior apophyseal articular processes.

TABLE III

Variation between the Angles of the Plane Made by the Right and Left Aspects of the Axiocervical Apophyseal Joint

Variation (*Degrees*)	No. of Specimens	Per cent.
0–5	6	33.3
5–10	3	16.6
10–15	2	11.1
15–20	1	5.6
20–25	1	5.6
25–30	3	16.6
30–40	1	5.6
Over 40	1	5.6

than 5 degrees from the normal angle of 90 degrees from the sagittal plane; the angle of inclination varied less than 5 degrees from the 45-degree angle; and the size varied less than three millimeters in all but one specimen. All of the remaining eighteen specimens showed significant changes in the axiocervical apophyseal articular processes. In most instances, these presented themselves by variations in the planes, the angle of inclination, and the size of the joint surfaces. There were degenerative arthritic changes in four specimens and an unusually shaped irregularity in one (Specimen 1690, Figs. 3-D and 4-D). Table I illustrates that there was asymmetry in either the plane, the angle of inclination, or the size of the joint in every specimen. Furthermore, the variations from normal were sufficient to be of significance in all instances. It will be seen in Table II that the variations between the planes or angles of inclination were less than 10 degrees in only 11.2 per cent., while in 49.9 per cent. the variations were from 11 to 20 degrees. The asymmetry in the

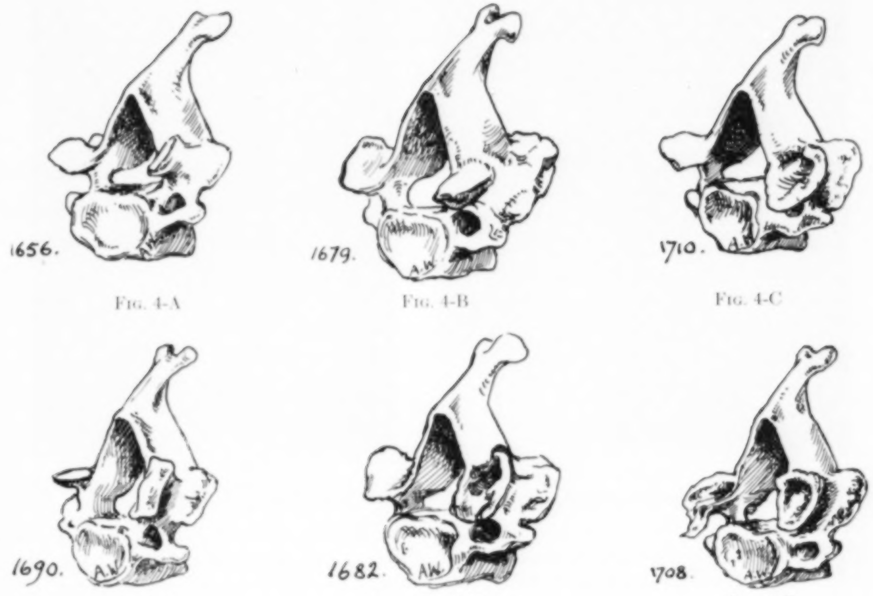

Fig. 4-A Fig. 4-B Fig. 4-C

Fig. 4-D Fig. 4-E Fig. 4-F

Drawings of the same vertebrae as shown in Figs. 3-A through 3-F but drawn from the superior semilateral view.

TABLE IV

Variation between the Angles of Inclination Made by the Right and Left Aspects of the Axiocervical Apophyseal Joint

Variation (*Degrees*)	No. of Specimens	Per cent.
0–5	6	33.3
5–10	5	27.8
10–15	3	16.6
15–20	0	0
20–25	1	5.6
25–30	1	5.6
30–50	2	11.1

planes and angles of inclination is demonstrated separately in Table III and Table IV. These reveal that the variations in approximately 50 per cent. of the planes and 61 per cent. of the angles of inclination were less than 10 degrees, while the variations in 50 per cent. of the planes and 39 per cent. of the angles of inclination ranged from 11 to 70 degrees.

A study of the differences in size between the right and left articular processes reveals a difference of three millimeters or more in 44.5 per cent. of the specimens (Table V). Table I shows that there were two specimens in which the difference was six millimeters (Specimen 10, Figs. 3-C and 4-C) and eight millimeters (Specimen 18). The articular facets were small in two instances (Specimens 2 and 7), and in one (Specimen 18) they were quite large, as compared with the average; one articular facet (Specimen 3, Figs. 3-D and 4-D) presented an angular, irregular surface. Degenerative arthritic changes were found in the articular facets of four specimens, in which the plane and the

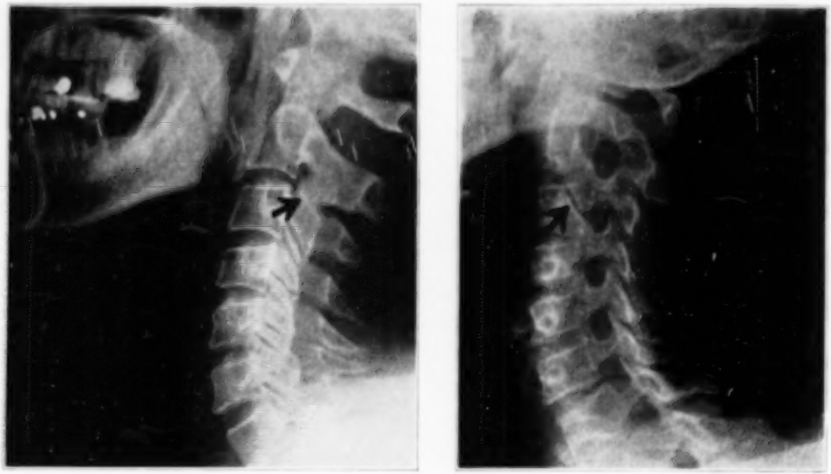
FIG. 5-A FIG. 5-B

Roentgenograms showing the axiocervical apophyseal joints to be in the oblique plane.

angle of inclination and size were such as to allow marked instability of the apophyseal joints (Figs. 3-A through 4-F). Therefore, one would interpret the changes as being the result of chronic trauma.

The evolutionary changes which have taken place in the development of man have been accompanied by a number of skeletal changes. Keith and Willis [10] have pointed out that one of these changes takes place as an evolutionary shortening of the spinal column, which has been accomplished by the broadening and flattening of all of the spinal segments, as well as by the inclusion of the last lumbar vertebra in the sacrum. Willis [11], Putti, Badgley, Hadley, and Fletcher have described the variations in the lower lumbar articulations and their effect on the stability of these articulations. Willis [11], from a study of some 1,400 skeletons, held the opinion that anomalies of the spine are confined particularly to the lumbosacral area of the spinal column and that they are a result of evolutionary, developmental, or environmental influences.

Our present study indicates that such changes are not confined to the lower portion of the lumbar spine. The series is too small for a statistical study, but it is sufficient to show that the changes occur frequently in the upper portion of the cervical spine.

Furthermore, the second cervical vertebra presents definite characteristics, such as a large spinous process, longer transverse processes, and many variations in the articular processes, all of which may be classified as transitional changes. These changes are comparable to those occurring in the lower lumbar vertebrae and would indicate that there is a tendency for the second cervical vertebra to be included in the vertebra above. All of these findings are phylogenetic in type.

The findings in the present anatomical study may offer a partial solution to the problem of the headaches which frequently accompany symptoms referable to the upper portion of the cervical spine as described by Josey. Willis's hypothesis that poorly developed and asymmetrically formed articular processes in the lumbosacral area strongly suggest mechanical instability and susceptibility to ligamentous injury is equally applicable to the upper portion of the cervical spine. Injury or chronic strain to these articulations may produce capsular ligament irritation and oedema.

A recent study by one of the authors [8] showed that twenty-one (11.3 per cent.) of 186 cases of cervical radicular pain had the pain localized to the third cervical nerve seg-

TABLE V

VARIATION IN SIZE (DIAMETER) BETWEEN THE RIGHT AND LEFT ASPECTS OF THE SECOND AND THIRD CERVICAL APOPHYSEAL JOINT

Variation (*Millimeters*)	No. of Specimens	Per cent.
0	3	16.6
1	6	33.3
2	1	5.6
3	2	11.1
4	3	16.6
5	1	5.6
6	1	5.6
8	1	5.6

ment,—namely, the scalp over the postauricular, occipital, and posterior parietal regions as far forward as the vertex of the skull.

Every case in this group revealed, through roentgenograms, variations in the apophyseal articular processes of the second and third cervical vertebrae (Figs. 5-A and 5-B). These findings tend to substantiate the hypothesis that irritation of the third cervical nerve does produce occipital headaches. The postorbital and frontal headaches are more difficult to explain. However, one can offer the hypothesis that the sensory nerves arising from each cervical nerve to join the cervical sympathetic system may carry similar pain impulses to that portion of the brain supplied by the carotid plexus with a resulting arterial spasm. That similar headaches accompany nerve-root irritation in the lower portion of the cervical spine offers some support for such a hypothesis.

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SCOLIOSIS COMPLICATED BY PARAPLEGIA

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In the forty-six previously reported cases of scoliosis complicated by paraplegia (Table I), the majority (thirty-seven) of the patients were in their teens, three were under ten years of age, and six were in their early twenties (Table II).

The high incidence in the second decade was presumed to be related to the often rapid increase of the deformity of structural scoliosis during early adolescence. The occurrence of paralysis in two of the three cases in the first decade of life may be explained on the basis of a sudden worsening of the deformity, especially of the congenital variety, which is not uncommon even at an early age. In fact it is now well established that a non-idiopathic scoliosis—such as a paralytic or other neurogenic curvature, the scoliosis associated with osteogenesis imperfecta, neurofibromatosis, or dystonia musculorum—may increase at any age. The third of the three patients under ten years of age was fifteen months old. The infant had had a wedge resection for a congenital scoliosis, and a postoperative kyphosis and paraplegia developed.

TABLE I

FORTY-SIX PREVIOUSLY REPORTED CASES

Authors	No. of Cases
Hyndman	1
Kleinberg *	1
Love and Erb	2
McKenzie and Dewar *	41
Wiles	1

* Including the first case of the present senior author.

TABLE II

AGE INCIDENCE IN FORTY-SIX CASES OF SCOLIOSIS WITH PARAPLEGIA

Age	No. of Cases
One to six years	3
Eleven to nineteen years	37
Twenty to twenty-three	6

The case to be reported is unusual because, although the scoliosis is apparently of the idiopathic variety, in which there is rarely any increase of the deformity after puberty, the paralysis did not appear until the patient was thirty-eight years old. The history also shows that he had not had any change of occupation, did not have to do laborious work, was not subjected to inordinately long hours of work, and had not suffered from any exhausting illness. So far as we can determine there was no unbalancing force, mechanical or otherwise, which could be held responsible for a sudden increase in the deformity and resultant paralysis. The patient was not aware of any increase in his deformity. Except

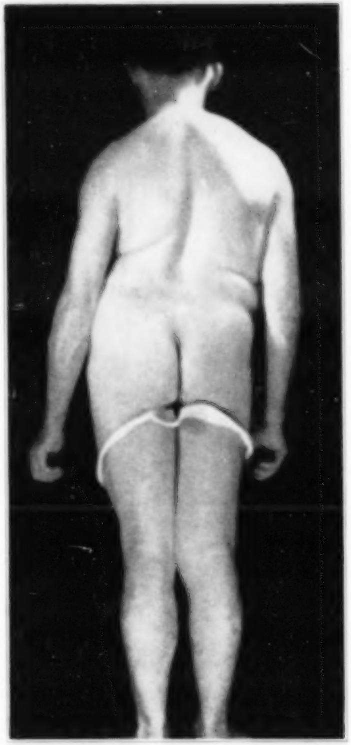

Fig. 1-A

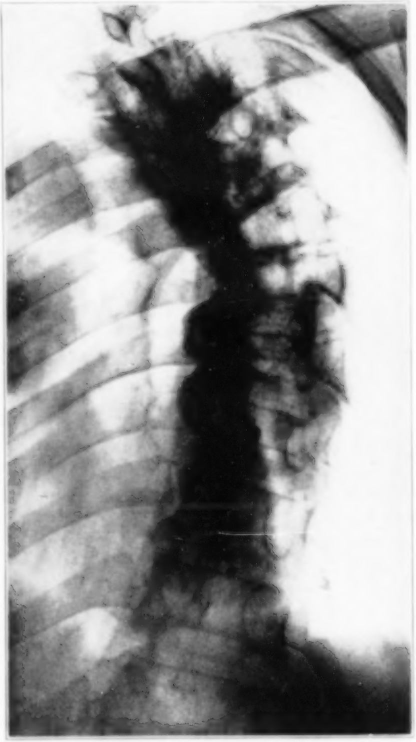

Fig. 1-B

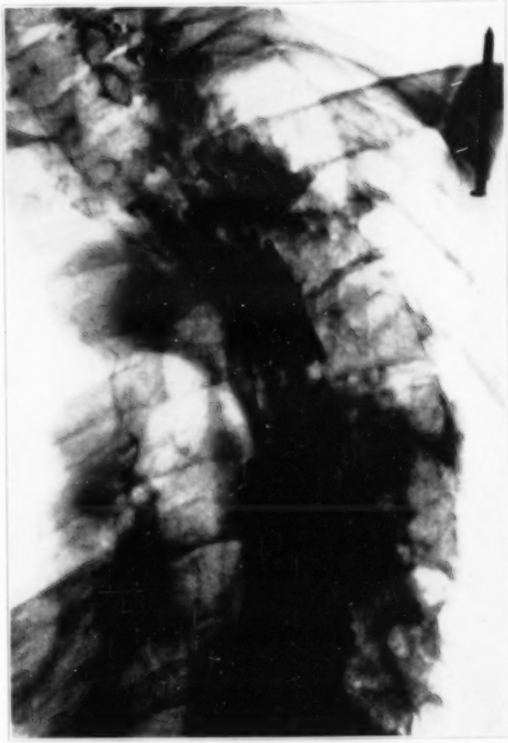

Fig. 1-C

Fig. 1-A: Photograph showing patient with a severe right dorsal kyphoscoliosis.

Fig. 1-B: Anteroposterior roentgenogram, showing a right dorsal scoliosis with the apex of the curvature and marked vertebral wedging at the fourth, fifth, and sixth thoracic vertebrae.

Fig. 1-C: Myelogram showing block at the level of the fourth thoracic vertebra.

for the age factor, our case is similar to all the others reported in that the deformity was a severe dorsal kyphoscoliosis.

It is interesting, too, to recall that the majority of the patients reported were males. Our present patient is a male. This feature is peculiar and difficult to explain since idiopathic structural scoliosis is at least four times, and in some groups as much as nine times, as frequent in girls as in boys. We are hardly justified in assuming that the physical activity of boys is much greater than that of girls and is therefore likely to initiate an increase in the curvature with consequent torsion and angulation of the cord and paraplegia. There are several arguments against this: (1) Teen-age girls with structural scoliosis are, generally speaking, just as active physically as boys with the same condition; (2) since girls with scoliosis greatly outnumber boys with scoliosis, one would expect to find paraplegia more frequently in girls than in boys; (3) the *X* factor which accounts for the initiation and the aggravation of a structural scoliosis is presumably the same in both sexes; (4) the severest type of scoliosis, the so-called "razor-back" deformity, is actually seen more commonly in girls than in boys, evidently because of the greater incidence of scoliosis among girls. Of course it should be emphasized that paraplegia is a rare complication in scoliosis. Including the present case, there are only forty-seven recorded cases of the complication in a deformity which afflicts many thousands of people throughout the world.

CASE REPORT

H. K., male, forty-three years old, came under observation at the Hospital for Joint Diseases in July 1950 for progressive weakness and stiffness of both lower limbs, worse on the right side, and increasing difficulty in walking. The family history is irrelevant, showing no instance of scoliosis in any other member. The patient's past history indicates that he became aware of his scoliosis at the age of ten years. He does not know how long the deformity had then been in existence. The scoliotic deformity increased during adolescence, but not, to his knowledge, after he completed his growth. During his adulthood and until the onset of his present difficulty, he had been physically very active. He worked hard, walked long distances, was able to lift heavy weights and frequently did, and attended to his daily duties as a salesman in a vegetable store; in short, he felt himself physically equal to those about him. He was married and had three children all of whom are well and free of scoliosis.

His present difficulty had begun five years before his examination at the Hospital with the gradual onset of stiffness and weakness in the right leg. He had not been working any harder than usual and had not suffered from any trauma, or from prolonged or enervating illness. The symptoms increased and he began to trip and fall. Occasionally the left lower extremity felt weak and some pain developed on the medial side of the knee. The disability progressively increased, so that two years later he had to give up his job and take on a sedentary position as an operator of a sewing machine. He worked eight hours a day, and had sufficient strength in his right leg to push and control the pedal of the machine. However, unaided walking became more difficult, and, as he put it, "it was a struggle". He had no discomfort in his back and no sphincteric disturbance. The locomotor instability steadily increased.

Examination showed that the patient was a well-built man, presenting a severe right dorsal kyphoscoliosis (Fig. 1-A). He walked without assistance, but with great difficulty, dragging his right leg. The gait was markedly spastic. The various body systems, including the thoracic and abdominal organs and the eyes, were normal. The back presented the typical appearance of a severe right dorsal kyphoscoliosis involving all of the thoracic vertebrae with the apex of the deformity at the level of the fourth and fifth thoracic vertebrae. There was moderate deviation but a marked rotation deformity with great prominence of the ribs and scapula on the right side. The roentgenogram (Fig. 1-B) showed a right dorsal scoliosis with wedging of the fourth, fifth, and sixth thoracic vertebrae. Neurologically this patient presented motor, sensory, and reflex changes. He had definite weakness of the muscles in both lower limbs, much more marked on the right side. He was able to elevate the right lower extremity from the examining table but could not maintain the elevated position for more than a few seconds. There was a distinct atrophy of the right thigh and calf muscles. The sensory changes began at the fourth thoracic vertebra. There was hyperaesthesia and hypaesthesia below the fifth thoracic vertebra. All modalities were equally affected, being more marked in the right limb than in the left. The abdominal reflexes were absent. There were bilateral pathological reflexes. There was a bilateral Babinski reflex, an inexhaustible right ankle clonus, and an exhaustible left ankle clonus. There was no bladder or rectal disturbance. The saddle area was apparently not affected. There was no evidence of an anterior-horn involvement. The cranial nerves were intact and there was no cerebral or cerebellar dysfunction. A myelogram with the use of pantopaque showed a block at the level of the fourth thoracic vertebra (Fig. 1-C). The block appeared like that seen in cases of chronic adhesive arachnoiditis.

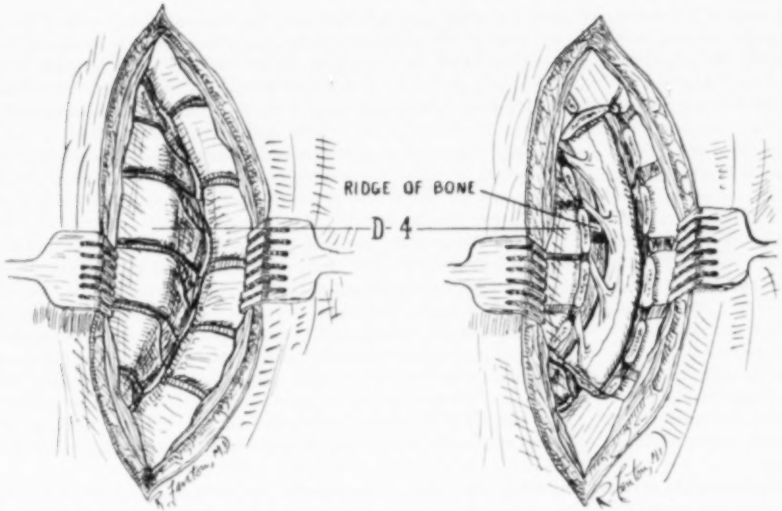

FIG. 2-A FIG. 2-B

Fig. 2-A: Drawing illustrating exposure of spine during laminectomy. Apex at the fourth thoracic vertebra.

Fig. 2-B: Drawing after removal of laminae from the second to the sixth thoracic vertebrae inclusive. The dura is not open. Note contraction and angulation of cord at the fourth thoracic vertebra; note also rotation of the cord, and the nerve roots visible on the concave side but not on the convex side. Nerve roots are directed cephalad instead of caudad. Note, too, the spur of bone pressing on the cord at the fourth thoracic vertebra.

The diagnosis of the cause of the manifest cord-compression symptoms lay between angulation and compression, secondary to the scoliotic deformity and an intraspinal tumor.

At operation, performed November 30, 1950, a seven-inch vertical incision was made in the medial line of the upper thoracic area of the back. The posterior arches of the thoracic vertebrae from the second to the sixth inclusive were exposed subperiosteally bilaterally. The curve of the spine was found to be somewhat less marked than we had anticipated from the roentgenogram. Nevertheless there was a severe deviation and rotation deformity (Fig. 2-A). A bilateral laminectomy was done, exposing the spinal cord from the second to the sixth thoracic vertebrae. Directly beneath the lamina was found a layer of extradural fat which was six to eight times the normal thickness. It extended over at least three segments, and as it was removed there was considerable bleeding from the bony structures. When the fatty tissue had been removed, the bluish dura came into view. The laminae on both sides were removed extensively, so that a good view of the cord was obtained and the spinal nerve roots were clearly visualized. A segment of the cord a little over three inches long was brought into view. The most conspicuous feature at this juncture was a marked posterior angulation at the level of the fourth thoracic vertebra. The upper and lower portions of the exposed segment of the cord formed an angle of about 150 degrees. At the apex of the angle, the cord was markedly constricted (Fig. 2-B). The cord pulsated above the constriction but not below it. It was further noted that the nerve roots instead of

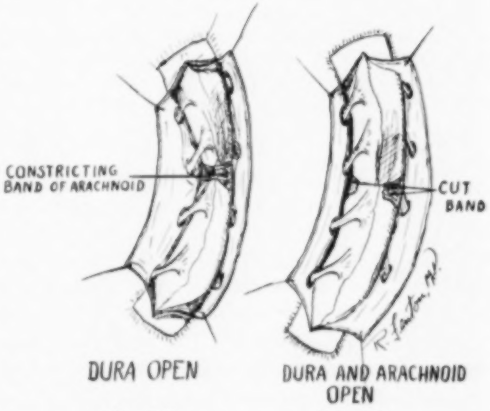

FIG. 2-C FIG. 2-D

Fig. 2-C: Note arachnoid adhesions and constriction of cord.

Fig. 2-D: Arachnoid adhesions have been cut and bony spur removed. The cord has derotated and the nerve roots are in nearly the same coronal plane.

being directed downward and outward coursed cephalad; moreover, the roots on the two sides of the cord were not in the same coronal plane; those on the left side were more posterior than those on the right side, indicating that the cord was not only angulated but abnormally rotated. When the dura had been opened, there was a free escape of subarachnoid fluid. A catheter directed upward met an obstruction; directed downward the catheter moved freely. The dura was opened more extensively and arachnoid adhesions were found (Fig. 2-C); these had formed a barrier to the passage of the catheter. After the arachnoid adhesions had been severed the catheter moved upward freely. There was no extradural or intradural tumor. The cord was gently rotated and its ventral aspect inspected; this was also found to be free from any tumor. It was quite evident that the apex of the spinal curvature encroached on the cord so that the cord was about half its normal thickness. In addition, at the level of the fourth thoracic vertebra, there was found on the concave side of the curve a spur or ridge of bone (Fig. 2-B) pressing on the cord (this pathogenic factor has been found and reported by others). When the dura had been freely cut and the arachnoid adhesions and the bony spur removed, the cord derotated so that the nerve roots appeared to be more nearly in the same coronal plane (Fig. 2-D). A liberal amount of bone was removed in both lateral directions so that the cord finally lay quite free from any pressure. The nerve roots were not severed, first, because the cord had been adequately mobilized and second, because we wished to avoid embarrassing the blood supply of the cord and did not want to risk the danger of a transverse myelomalacia. The dura was left open. This has in the past been found to be an indispensable part of the technique. Gelfoam was used to cover the cord. After careful hemostatis and irrigation with penicillin the wound was closed in layers. No attempt was made to bridge the bony defect caused by the operation with osseous grafts, since we wished to assure maintenance of the spinal decompression.

The immediate postoperative course was quite uneventful. The patient reacted well and had minimal discomfort. The wound healed by primary union. He was observed carefully during the following few weeks. For a brief period the outlook seemed encouraging because the Babinski reaction on the left side became equivocal, and on several occasions the previously existing ankle clonus on the left side was absent. One of us even thought that the motor power in the right leg was improved (perhaps this was only wishful thinking).

However, several months after the operation, the patient was again examined. At this time he came to the Hospital aided by his wife and son. He stated that his lower extremities felt weak, stiff, and shaky, and that he was worse than before the operation. In his home he got about with the aid of a cane and by holding on to various objects. In the street he could walk only with the help of two people. We concluded that in this, as in so many other reported cases, the decompression operation had been delayed too long, with the result that the spinal cord was irreparably damaged.

However, on November 12, 1951, the patient was again examined. At that time he showed great improvement in motor function. He entered the office aided only by a cane and was even able to walk without a cane. He had no spasticity in the left lower extremity and greatly diminished spasticity in the right extremity. He felt so encouraged that he was about to return to his former employment.

SUMMARY

We believe this to be the first reported case of scoliosis complicated by paraplegia in a man in the fifth decade of life. Since the patient's history is non-contributory and there is no evidence of any recent increase in the deformity, it is difficult to explain the unusually late onset of the paralysis. The scoliosis is similar in type and degree to those previously described; it is a severe dorsal kyphoscoliosis with marked deviation and rotation deformity of the thoracic vertebrae.

During the laminectomy two causes were found for the neurological symptoms. One was the severe angulation and rotation of the cord, and the other was pressure on the cord by a nubbin of bone on the concave side of the curvature at the level of the apex of the deformity. The spur of bone invaded the neural canal and lay against the cord. Either factor alone, and certainly both in combination, would have been sufficient to cause compression of the cord. The scoliosis which appeared in childhood was probably of the idiopathic variety, but might also belong to the group which the senior author has classified as congenital scoliosis without manifest malformation of bone, such as wedged vertebrae and asymmetrical development [3].

The lesson which this case holds for us is that, as soon as a case of structural scoliosis shows signs of cord compression, an adequate decompression laminectomy should be promptly performed and the area of compression thoroughly explored for such compressive elements as a spur of bone, a tight dural band, or taut nerve roots. In some cases transposition of the cord is necessary to relieve it completely from undue pressure.

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THE ANATOMY OF THE PELVIC TEAR FIGURE

BY VICTOR B. VARE, JR., M.D., ANN ARBOR, MICHIGAN

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The pelvic tear figure or "tear drop" is a roentgenographic landmark seen in the anteroposterior view of the pelvis. The relationship of the tear drop and the adjacent

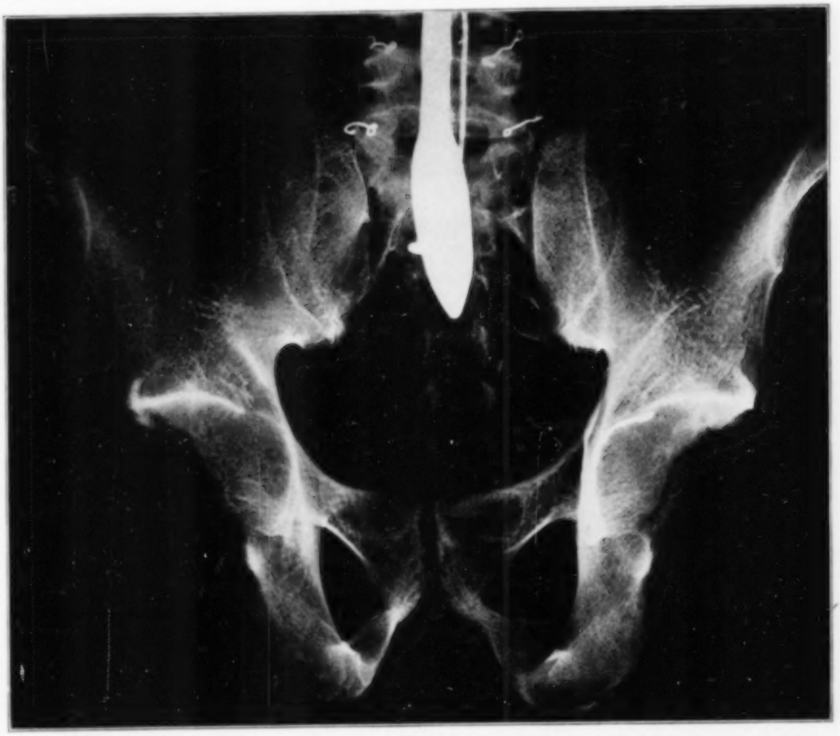

FIG. 1

The tear drop is visible on the right and is enclosed in lead foil on the left side.

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* Carl E. Badgley, M.D., Director

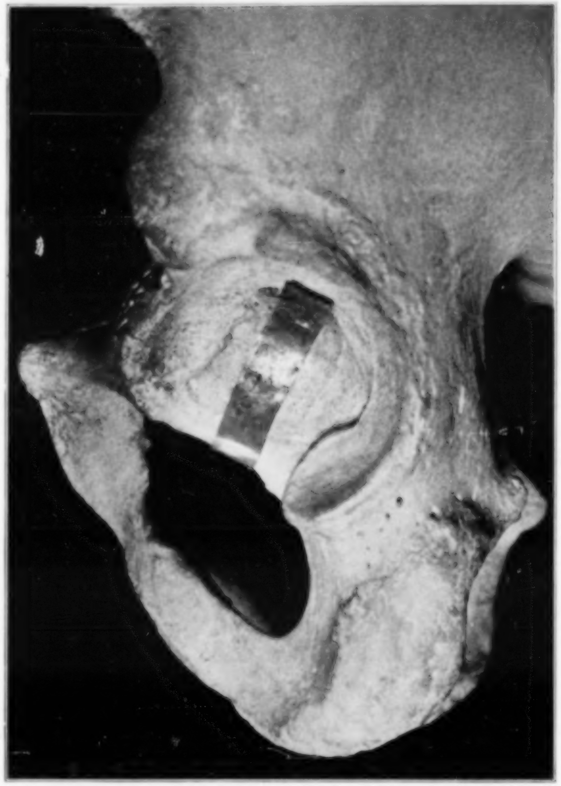

FIG. 2

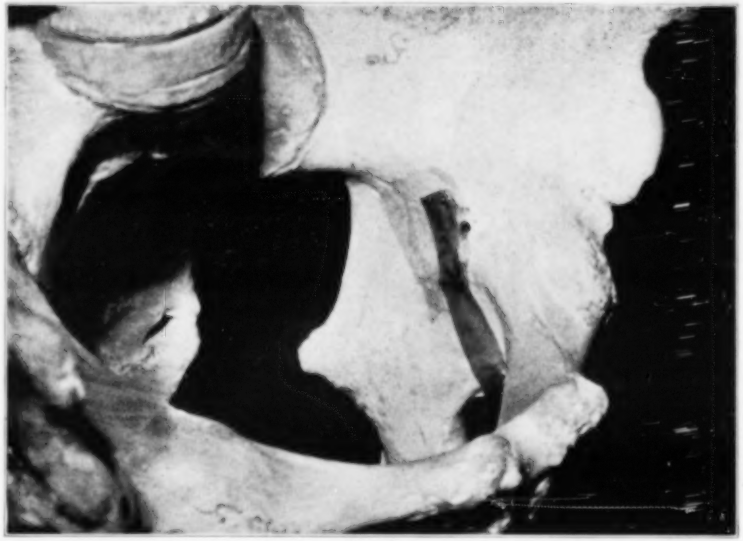

FIG. 3

Fig. 2: Lateral photograph of the pelvis, showing position of the lead foil in the acetabulum .

Fig. 3: Superomedial photograph of the pelvis, demonstrating the position of the lead foil in the true pelvis.

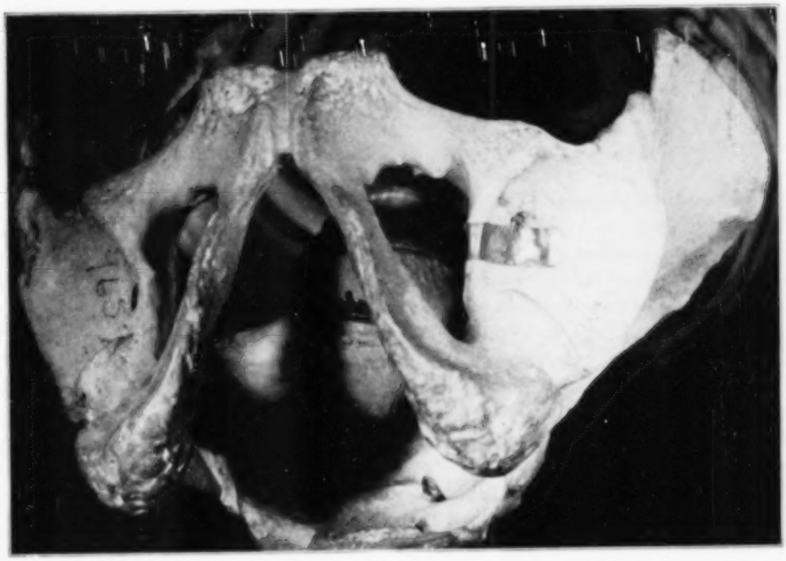

FIG. 4

Inferior photograph of the pelvis, demonstrating the position of the lead foil in the cotyloid notch.

structures is remarkably constant under normal circumstances. Alteration of this relationship, however slight, especially when compared with the opposite side, suggests pathological changes either in the pelvic bones in the vicinity or in the structures which make up the hip joint in general.

The anatomy of the pelvic tear figure is difficult to determine because there are no correlating features seen in the lateral roentgenograms. As a consequence, a method of trial and error was used with metal markers and repeated roentgenograms to locate the structure concerned. After several attempts the tear figure was outlined by means of a 12-millimeter strip of malleable lead foil, as demonstrated in Figure 1.

The anatomy of the structure is presented pictorially in Figures 2, 3, and 4, demonstrating the lead foil *in situ*. The lateral border of the pelvic tear drop, therefore, is made up of the cortical surface of the middle third of the acetabular fossa, commencing at the lunate surface proximally and extending to the cotyloid notch inferiorly. Continuation through the obturator foramen marks the inferior aspect of the roentgenographic structure. The medial aspect of the tear figure is made up of the cortical surface in the true pelvis, where a groove for the obturator vessels and nerve exists, continuing in the same plane as far as the arcuate line immediately posterior to the iliopectineal prominence.

MILKMAN'S PSEUDOFRACTURE

A Form of Osteomalacia

BY DONALD J. MAGILLIGAN, M.D., AND PETER J. DULLIGAN, JR., M.D., BROOKLYN, NEW YORK

In 1930, Milkman reported a case of "pseudofractures", a forty-year-old white female, suffering from multiple, symmetrical, incomplete fractures, which had gradually been increasing in number over a period of five years. Following his report, Milkman discussed the writings of many Central European authors, who reported similar cases of pseudofracture following World War I. He mentioned particularly the studies of Looser who concluded that hunger osteopathy, late rickets, and osteomalacia are the same disease, but differ in their clinical manifestations because of the different age groups in which they are found. After eliminating fragilitas ossium, multiple myeloma, mestastatic malignancies, lues, dystrophia myotonica, inflammation, and exophthalmic goiter as possible causes, Milkman classed his case with those of Looser, but stated that the basic etiological factor is unknown.

In a second article in 1934, Milkman presented a follow-up report of the same patient with autopsy findings. He stated that this case represents a distinct new clinical entity and that it is not one of osteomalacia; however, two of the three pathological reports on the autopsy bone specimens were given as osteomalacia. He suggested that the zones of radio-lucency, the pseudofractures seen on x-ray examination, are due to some trophic disturbance, and that there is a peculiar typical pattern of bone absorption which is atypical for any known disease entity. It is to be noted that, in his discussion of treatment, he stated that there was no evidence of endocrine disturbance; yet he reported that in the late stages of his patient's illness diabetes developed. In the autopsy findings, no mention is made of any pathological examination of the pancreas. Although his patient had been given large doses of phosphorized vitamin D and heliotherapy, the fact that vitamin-D resistance might be an etiological factor was not considered. No mention is made of any studies of gastro-intestinal function.

In a more recent text Albright and Reifenstein present a somewhat different viewpoint. The following paragraphs outline some of their concepts as to the nature of Milkman's syndrome, as well as its etiology and diagnosis.

According to these authors, Milkman's syndrome is a form of osteomalacia. This is considered by them to be a disorder of calcium and phosphorus metabolism in which the bony matrix is formed normally up to a point, but the calcium salts are not deposited in the newly formed osteoid tissue. They also believe that osteomalacia is distinguished from osteoporosis by the fact that in the latter the osteoblasts lay down too little bony matrix, although that which is laid down is normally calcified. Rickets has all the characteristics of osteomalacia plus additional changes at the growing epiphyseal cartilage, notably faulty calcification of the zone of provisional calcification. For this reason osteomalacia is sometimes termed adult rickets.

Albright and Reifenstein classify osteomalacia into four types: chemical osteomalacia with normal phosphatase, chemical osteomalacia with high phosphatase, Milkman's syndrome, and advanced osteomalacia. According to these authors, in Milkman's syndrome there is not only alteration of the calcium and phosphorus concentration in the serum but also there are pseudofractures. There are several reasons for the classification of Milkman's syndrome as a form of osteomalacia:

1. The symmetrical pseudofractures or zones of decalcification are also seen in rickets and were described by many German physicians, following World War I, in people with marked dietary deficiencies[2].

2. Lesions resembling pseudofractures occur in conditions other than osteomalacia, but they always occur through areas of bone obviously pathological, while in osteomalacia the pseudofractures appear in bone that has an otherwise normal x-ray appearance.

3. Review of the cases of Milkman's syndrome reveals the serum-calcium and phosphorus levels to be consistent with osteomalacia.

4. There are excellent responses to therapy with vitamin D and other fat-soluble vitamins.

Albright and Reifenstein classify the etiologies of osteomalacia met in the United States as follows:

A. Vitamin-D lack
   a. Simple vitamin-D lack
   b. Resistance to vitamin D
   c. Steatorrhoea
B. Renal acidosis
   a. Tubular insufficiency without glomerular insufficiency
   b. Fanconi syndrome
C. Idiopathic hypercalcuria
D. Hyperparathyroidism with osteitis fibrosa generalisata during transitional state, following removal of parathyroid tumor.

The commonest cause of hypovitaminosis D in adults in the United States is steatorrhoea. The two chief causes of steatorrhoea in this country are: (1) an idiopathic steator-

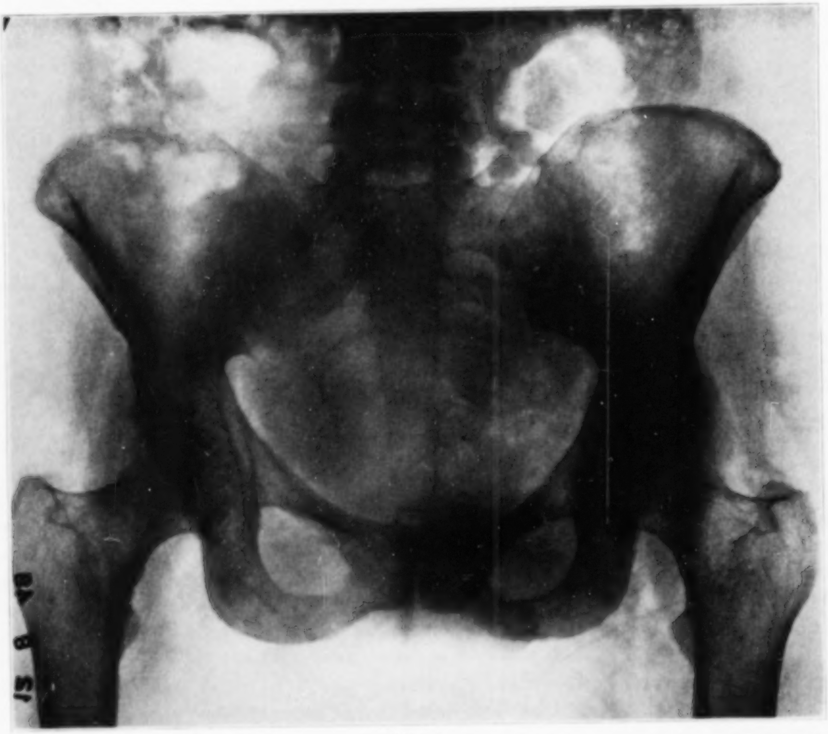

Fig. 1

An anteroposterior view of the pelvis reveals bilateral, symmetrical pseudofractures of the inferior cortices of the necks of both femora.

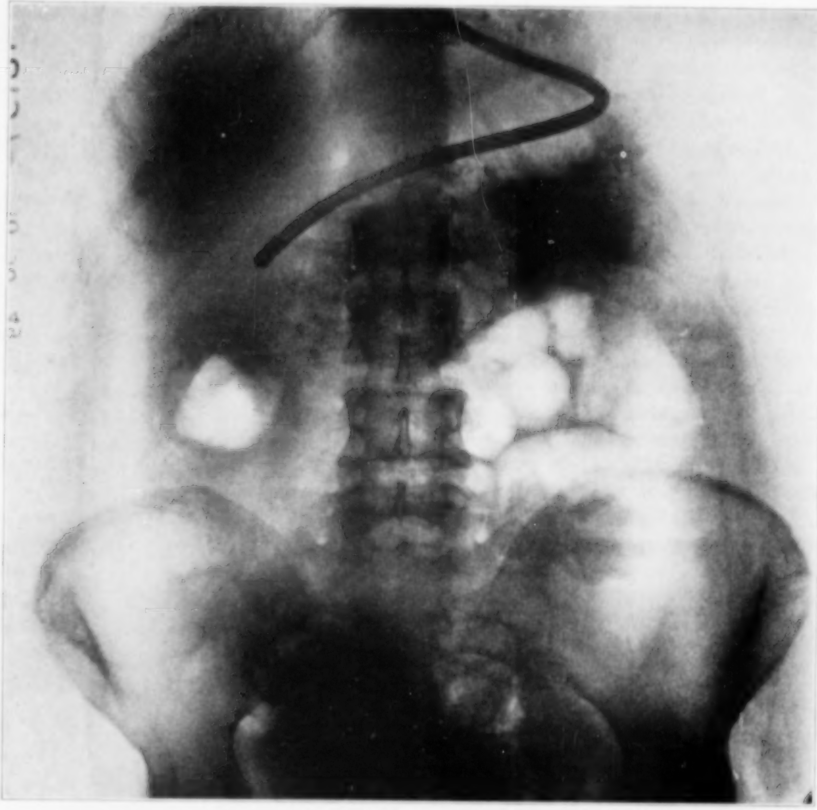

FIG. 2

October 10, 1949. A flat plate of the abdomen, taken for placement of a tube in the duodenum, revealed multiple pancreatic calculi and disclosed the etiology of the patient's steatorrhoea.

rhoea which is called non-tropical sprue or, in children, coeliac disease, (2) chronic pancreatitis. A third cause of steatorrhoea is insufficiency of the small intestine, resulting from any one of a number of causes but often from short-circuiting operations.

DIAGNOSIS

The diagnosis of osteomalacia due to steatorrhoea often remains unrecognized for a long time, especially where diarrhoea is not a prominent feature. There is frequently a history of chronic upper-abdominal pain attributed to gall-bladder disease. Stools in which the fecal fat value is over 10 per cent. of the intake or over 25 per cent. of the dried fecal weight are strongly suggestive of steatorrhoea. This results in a loss of the fat-soluble vitamins A, D, K, and E in the stool, plus deficiency of calcium absorption from the intestinal tract. Thus, improper calcification of bone occurs and pseudofractures appear at points of greatest stress and strain,—such as the necks of the femora, the rami of the pubic bones, and the axillary borders of the scapulae.

In our own observations it has been noted that at times symmetrical pseudofractures of the femoral necks have been thought to be due to stress alone. A recent case report [5] presents this viewpoint. A review of this case report reveals a very significant history of chronic diarrhoea for several years. The patient responded to treatment which consisted of a high calorie diet, a multiple-vitamin preparation, and 10 minims of dilute hydrochloric acid three times daily. This was the only treatment aside from bed rest. It is entirely possible that this case of "stress fractures" may ultimately prove to be one of osteomalacia with pseudofractures, because of the suggestive history of steatorrhoea and also because of the response to dietary and vitamin preparations.

The following case presentation, in our opinion, illustrates the fact that the pseudofractures seen in the roentgenograms and diagnosed as Milkman's syndrome are not the result of some unknown etiological factor but rather represent advanced stages of osteomalacia. This case is presented as one of osteomalacia with pseudofractures, sometimes called Milkman's syndrome.

H. Q., a white female, forty-five years old, was admitted to St. Mary's Hospital, Brooklyn, on December 1, 1948, with complaints of pain in the left hip region, loss of weight, and a disturbance in gait. These symptoms had been present for a period of two years, during which time she had consulted many physicians. In the six months prior to admission, her symptoms had grown much more severe.

In her past history, the patient stated that she had been treated for attacks of acute cholecystitis four and six years ago. She also stated that for an indefinite period of months, she had noted that her stools had a "greasy" or "fatty" appearance.

The physical examination revealed an asthenic middle-aged female who weighed eighty-seven pounds. Her normal weight was 110 to 115 pounds. There was no acute pain at rest, but the patient had difficulty walking and complained of pain in the left hip and thigh. She had a waddling gait. The remainder of the physical examination was essentially negative, except for generalized muscle weakness and muscle atrophy in her lower extremities.

X-rays were taken of the hips and bilateral symmetrical pseudofractures were detected in the femoral necks (Fig. 1). Further x-ray examination, including the skull, chest, and long bones, revealed a decrease in bone density but no additional pseudofractures.

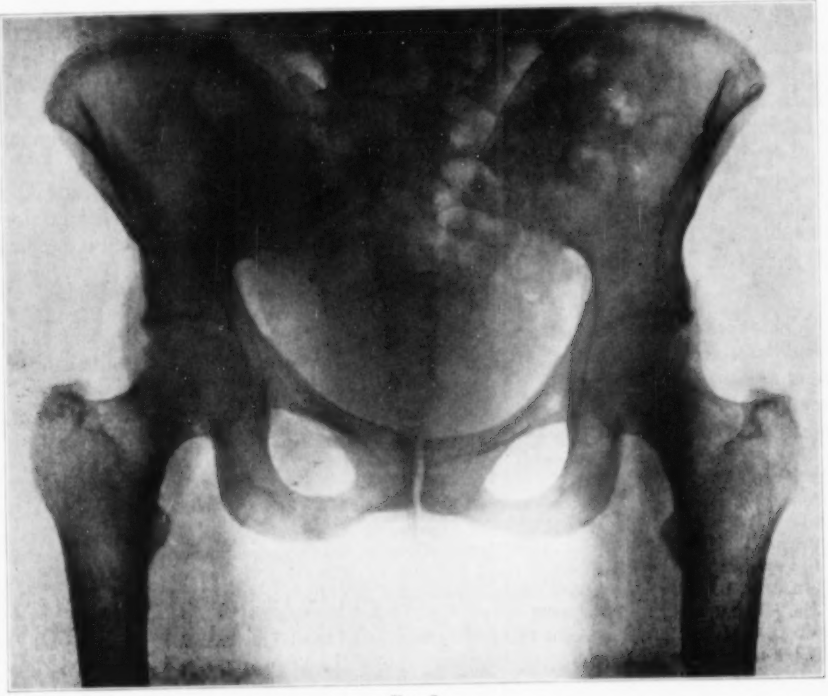

FIG. 3

October 7, 1949. An anteroposterior view of the pelvis, taken after treatment, reveals the healing of the pseudofractures in the femoral necks.

The blood calcium was 10.6 milligrams, the phosphorus 4.005 milligrams per 100 cubic centimeters of serum, and the alkaline phosphatase 6 King-Armstrong units.

The tentative diagnosis of Milkman's syndrome was made.

The patient was discharged, but she was re-admitted for further study on May 6, 1949. At that time she complained of pain in both hips and in the right shoulder, together with great difficulty in walking because of pain and muscle weakness.

A diet containing 100 grams of fat per day was given, and a stool specimen was obtained after nine days. This was analyzed for its total fat quantity. There was 36.75 per cent. total fat in the specimen and 37.01 per cent. on a dried basis. (A fecal fat value which is over 10 per cent. of the intake or over 25 per cent. of dried fecal weight is strongly suggestive of steatorrhoea.)

Her blood calcium had now fallen to 9.4 milligrams per 100 cubic centimeters of serum and the phosphorus had risen to 4.650 milligrams. The alkaline phosphatase had also risen, on this admission, to 20 King-Armstrong units. This was consistent with osteomalacia, in which the blood calcium is normal or low, the phosphorus normal or low, and the phosphatase elevated.

The patient was placed on an emulsifying agent (sorbital mono-oleate) to increase fat absorption. She was also given multi-vitamins containing 15,000 units of vitamin D daily. Before her medical survey could be completed, the patient had signed herself out.

The patient was re-admitted for further study on October 6, 1949. She then weighed ninety-five pounds, had lost her waddling gait, and was free of pain. A gastro-intestinal series of x-rays was negative, but a flat plate of the abdomen, taken while a tube was being passed for duodenal drainage, revealed multiple pancreatic calculi (Fig. 2). Her fasting blood sugar was 94.2 milligrams per 100 cubic centimeters and her glucose-tolerance test was normal. The mechanism of the patient's disturbance was thus revealed as a chronic pancreatitis with pancreatic calculi. Her resultant steatorrhoea had caused an excessive loss of fats and with this of the fat-soluble vitamins A, D, K, and E. In addition, the normal mechanisms of calcium and phosphorus metabolism were disturbed.

The patient was given pancreatin, crude liver extract, and folic acid plus her vitamins and sorbital mono-oleate (sorleate) which had been previously prescribed.

At last report, the patient had gained thirteen pounds in weight and was asymptomatic.

Absorption of calcium from the intestinal tract is regulated by Vitamin D. Absorption occurs mainly in the upper part of the small intestine. An important role is played by the pH of the contents of the intestinal tract. Most calcium salts are insoluble in alkaline fluids. Acidity of the intestinal contents is, therefore, a prerequisite for normal absorption of calcium. The acidity in the small intestine is raised by the intake of fats. Calcium may combine with fatty acids to form soaps if the production of bile or pancreatic juice is disturbed. In such cases, absorption of calcium, fats, and the fat-soluble vitamin D is diminished. Unabsorbed calcium in the intestine may also unite with phosphorus to form insoluble calcium phosphate and through this mechanism both calcium and phosphorus can be lost to the body.

SUMMARY

This case of symmetrical pseudofractures involving both hips illustrates the fact that pseudofractures are associated with osteomalacia in its advanced stages and that these pseudofractures are sufficiently similar to those described by Milkman to suggest that they have the same basic etiology. It is to be noted that Milkman's case report describes an associated pancreatic disease, diabetes.

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A PROSTHESIS FOR THE FEMORAL HEAD

A PRELIMINARY REPORT *

BY J. E. M. THOMSON, M.D., LINCOLN, NEBRASKA

From The Lincoln Orthopaedic Clinic

Prostheses for the femoral head have not been in use long enough to justify final evaluation in the treatment of painful pathological disabilities of the hip joint. Those who have had the temerity to try certain of these prosthetic devices, however, have been impressed by the early good function and comfort they frequently give.

Smith-Petersen has conclusively shown that the hip joint will not only tolerate weight-bearing and motion, but thrive when these forces are brought to bear upon it through a foreign body, such as a Vitallium cup, moving freely between the acetabulum and the reshaped head of the femur. This fact, we believe, has encouraged much of the interest in prosthetic devices for those hip conditions in which the cup is not suitable.

In the development of the various types of prosthesis, there seem to be at least two widely divergent opinions regarding the proper mechanical distribution of stress from the prosthetic head to the shaft of the femur. The one emphasizes the importance of transmitting this stress indirectly from the prosthetic head and neck rigidly to the shaft by means of a plate and screws or an intramedullary pin (Moore and Bohlman, Jaenichen and Collison [6], Lorenz and Steele, McBride, and Hudack). The second holds that the stress of weight-bearing should be transmitted directly to the strong bony architecture of the neck and by transfixion of the prosthesis to the strong lateral cortical portion of the shaft (Judet and Thomson).

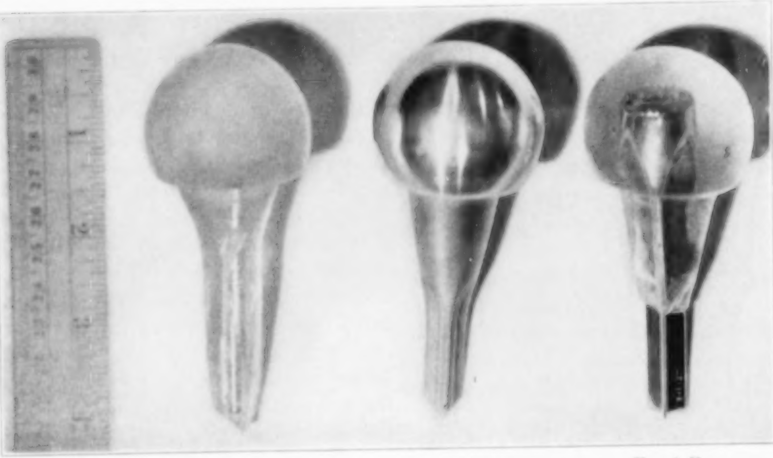

FIG. 1-A FIG. 1-B FIG. 1-C

Fig. 1-A: Thomson type acrylic prosthesis reinforced with a quarter-inch steel pin (Ferciot).
Fig. 1-B: Vitallium prosthesis.
Fig. 1-C: Original design, in which the prosthesis is cast on a triflanged nail.

We do not propose to argue the virtues of one type of prosthesis against others. Perhaps each of the principles used has a distinct place. However, the indirect plate-and-screw and intramedullary-pin methods involve extensive operative ventures which are more mutilative than the direct transfixion method here described. In the former, there would seem to be some opportunity for fracture of the shaft or breaking of the screws or plate. On the other hand, the latter type requires simple exposure of the hip joint without interference with the shaft and gives immediate early stability.

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* Original manuscript received March 31, 1951.

In aseptic necrosis, hypertrophic changes, and in other deformities of the head, in younger patients in whom a sufficiently long neck can be preserved after removal of the pathological material, the Vitallium cup or a Judet type of prosthesis can be used. However, in cases of non-union of the femoral neck in which the distal portion of the neck has been absorbed, and in some fresh fractures in old people in which internal fixation does not offer a very good chance of union, the Judet type is not so suitable, because the collar of this mushroom type of prosthesis must be seated on a long and well-shaped neck to provide stability.

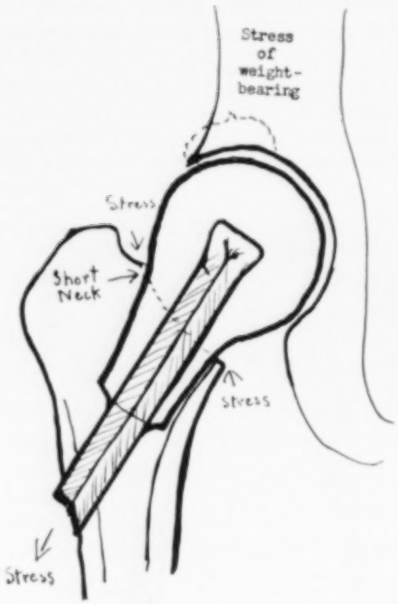

FIG. 2

A drawing to show the proper placement of the prosthesis against the cortical margin of the neck; the end of triflanged nail is driven into the lateral cortex. Note the distribution of weight-bearing stress.

When this prosthesis was being devised originally, with the three-flanged nail, the fact was considered that, if the Smith-Petersen nail is appropriate for internal fixation of fractures of the neck of the femur, it should be ideal for fixation of a prosthesis for the head of the femur. In other words, the nail with the plastic head and neck, once it is embedded in the base of the neck and impacted in the strong lateral cortex of the femur, acts in the same way as it would when passed through a similar course in the opposite direction from the lateral cortex into the stronger bony portion of the head in the treatment of a fracture. An advantage, however, of the prosthesis attached to a triflanged nail is that, while the stress from the plastic head and tapered neck is distributed to the entire cortical portion of the fractured neck, it is fixed to the lateral femoral cortex by means of the end of the nail, so that stability is not dependent on the nail alone.

Because of the similarity of the prosthesis in shape to an electric-light bulb, we have called this the "light bulb" type of prosthesis. With time, variations of the original conception have been evolved, and we feel these should add to stability. The specifications are briefly:

The ball head is one and one-half inches in diameter. There is a ledge at the lower third of the ball head, and from this point the oval tapered neck extends for a length of one and one-half inches; the triflanged nail protrudes from the slender one-half inch end of the plastic portion. The tapered neck is oval to correspond to the shape of the inner cortical portion of the neck of the femur. The over-all length of the prosthesis is four inches. The acrylic portion is cast on a Vitallium or SMo steel triflanged nail, three and one-half inches in length (Fig. 1-C). Occasionally, we have used an over-all length of four and one-half inches, using a nail three and three-quarter inches in length. If there is a longer femoral neck, a more oblique angle (135 degrees) for insertion will be tolerated but, if there is a short neck, a more acute angle (about 125 degrees) will be more satisfactory.

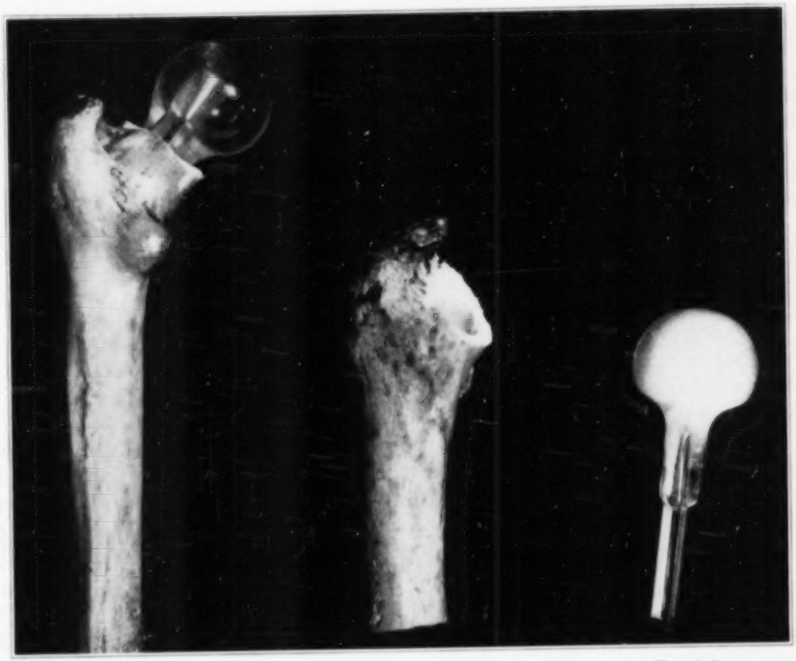

FIG. 3-A
Prosthesis in place.

FIG. 3-B
Bed made in neck.

FIG. 3-C
Prosthesis.

More recently, we have developed a similarly shaped Vitallium prosthesis (Fig. 6-A and Fig. 6-B) and also one (devised by Ferciot) which is made of acrylic reinforced with a one-quarter inch SMo rod (Fig. 1-A).

These variations of materials used have in no way altered the fundamental principle involved. This prosthesis, which follows in shape the normal head of the femur and the contour of the strong inner cortical portion of the neck, distributes the stress of weight-bearing and movement over the neck along anatomical lines. Implanting the end of the prosthesis in the lateral cortex at the proper angle stabilizes the prosthesis (Figs. 2, 3-A, 3-B, and 3-C).

Experience with modifications of the light-bulb type of prosthesis has been equally satisfactory. It was felt that the reliability and lasting qualities of acrylic had not yet been established, and that a weakness might develop at the union of the cast acrylic and the triflanged nail. As yet, we have had no such complications. More recently Vitallium prostheses have been used in younger patients, because the lasting qualities of this metal seemed more assured.

After a few months of use, roentgenograms reveal the increased bone density around the margin of the acrylic. This is evidence of increased bone strength and attests to the stability of the prosthesis (Fig. 4-B). The bone about the end of the nail in the lateral cortex is more dense and, if the nail protrudes slightly, it often becomes covered with cortical overgrowth. Should further absorption of the neck occur, the prosthesis can simply settle more surely into its bed.

The indications for the use of the light-bulb type of prosthesis at present are limited; the chief indications are as follows:

1. The prosthesis may be used for older people, particularly patients over sixty-five. Our knowledge of the durability of plastics under stress and weight-bearing is meager

but sufficiently reassuring to justify the assumption that it will provide several years of useful function.

2. The light-bulb prosthesis is also indicated if the patient is in a state of health that would justify any type of reconstructive operation, and the expectation of early function, ambulation, and weight-bearing.

3. It is also suitable in fresh fractures of the neck of the femur with a sheering angle, and those in which the distal segment of the neck is short or in which there is little opportunity of union by ordinary internal fixation.

4. This procedure is best suited for cases of non-union, particularly if there is a short femoral neck.

TECHNIQUE

Adequate preoperative preparation is absolutely essential. Organic and metabolic deficiencies must be well compensated. Choice of anaesthesia is of utmost importance. In old people spinal anaesthesia in small doses, with the blood pressure carefully controlled, has proved ideal. Fresh blood and fluids must be available.

The conventional anterior approach to the hip joint was used in the first nine cases. Through this exposure, however, it is frequently difficult to remove all of the capsule and visualize the operative field; therefore, with but a few exceptions we have used the posterolateral approach described by Gibson in all the later operations. It is our opinion that this incision is less traumatic and shocking. By this approach one obtains excellent

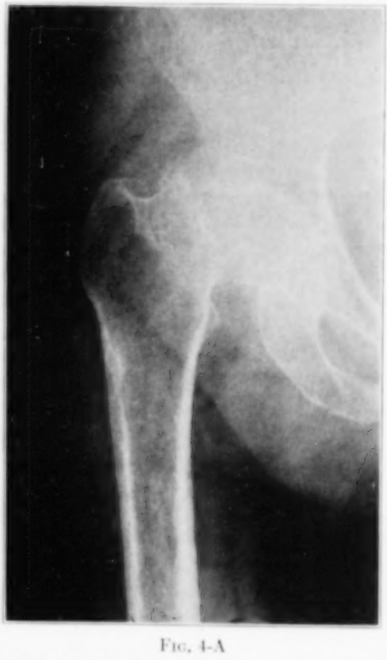
Fig. 4-A

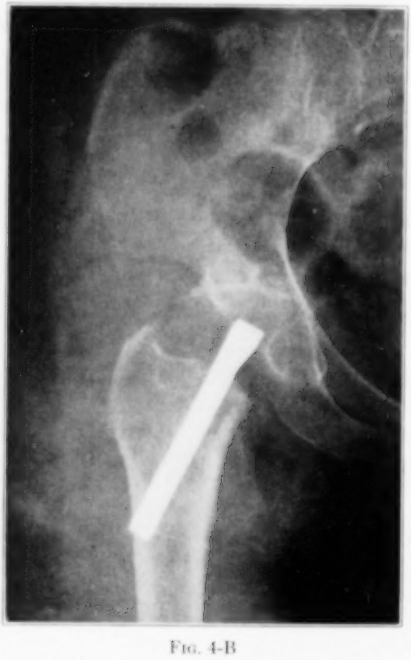
Fig. 4-B

Fig. 4-A: M. T., female, aged sixty-seven. This patient had sustained a fracture of the neck of the femur in 1946 which had appeared to heal, but non-union later developed. She was on crutches from 1947 until the prosthesis was applied.

Fig. 4-B: Roentgenogram made after the operation, performed on April 17, 1950. A light-bulb type of prosthesis was used.

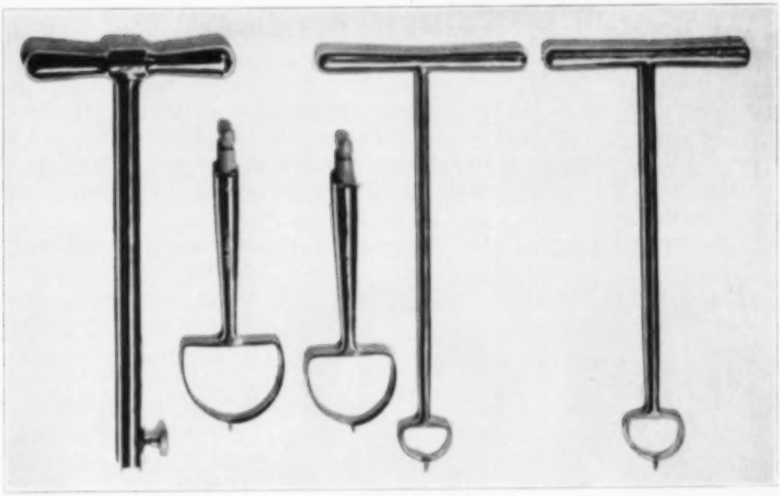

FIG. 5

Gruca acetabular reamers are semicircular one-way cutting instruments. Each has a screw or point in the center which enables the operator to center his reaming and continue at the same angle.

exposure of the parts involved in the operative procedure. When the head is dislocated from the acetabulum, it faces directly toward the operator. The acetabulum can be completely visualized and reamed out, and the anterior and inferior capsule can be removed readily.

The patient is placed on an ordinary operating table, lying on the side opposite the affected lower extremity. He is held in this position by a kidney rest, sand bags, or firm adhesive strapping of the trunk. The upper knee is flexed and the limb adducted across the other extremity. This brings the greater trochanter into prominence. The incision is started from the anterior prominence of the greater trochanter and extends longitudinally and distally along the anterior contour of the femur for six or eight inches (15 or 20 centimeters) and through the tensor fasciae latae. This enables the operator to outline the contour of the proximal portion of the trochanter and to continue his incision above the trochanter upward and obliquely backward about three and one-half to four inches, (8.75 to 10 centimeters), following the line of cleavage between the fascia covering the glutaeus medius and glutaeus maximus. The glutaeus maximus and tensor fasciae latae are reflected backward. Then, with a hemostat, the tract of the trochanteric bursa below the glutaeus medius at its insertion into the trochanter is identified and the tendon is separated by sharp dissection from its insertion and reflected upward. This brings into view the glutaeus minimus, the insertion of which is likewise severed after it has been identified with a hemostat inserted under tendon fibers at the trochanter. This muscle together with the glutaeus medius is reflected upward.

The lateral or superior portion of the ligamentous structures and the capsule of the hip joint are now directly in front of the operator and the acetabular margin and head can be palpated and identified. An incision is made, extending from the acetabulum along the neck toward the trochanter to the insertion of the capsule. From this incision, the capsule is then resected from its attachments to the acetabulum along the posterolateral and anterolateral portions. The head and neck can be distinctly visualized when this is completed.

When the operation is performed for fracture of the neck of the femur, the operator, by further flexing the knee and externally rotating the limb, can cause the fracture surface of the distal fragment of the neck to be turned up. Once this is accomplished, the head can be dislocated with a skid or a curved acetabular gouge.

On the other hand, should the prosthesis be put in as a replacement in malum coxae senilis or aseptic necrosis of the femoral head, dislocation is accomplished by the manoeuvres described, and the head is cut off transversely with a motor saw or a wide osteotome. When an osteotome is used, it should be directed half-way through the neck from several angles. Unless this precaution is followed, one is likely to shatter one side of the cortical portion of the neck.

After the removal of the head, the remnant of capsule can be distinctly identified and entirely removed. This procedure seems to contribute to the postoperative comfort of the patient.

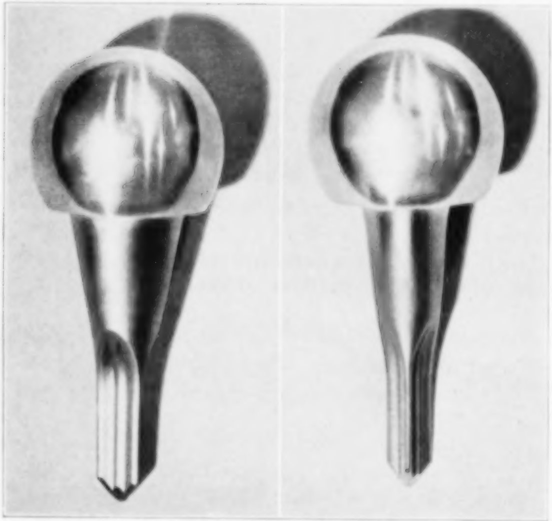

Fig. 6-A Fig. 6-B

The oval-shaped tapered portion of the prosthesis is inserted in such a way that the long axis points in a superior and inferior direction and the short axis in an anterior and posterior direction. This follows the normal anatomical contours of the neck of the femur.

The acetabulum is then thoroughly cleansed of soft tissue and debris. The articular cartilage may appear perfectly healthy and firm, but in old people is often soft, irregular, and abnormal in appearance. Therefore, we completely ream out the acetabulum, making it larger and deeper, thereby giving a better seat for the prosthesis and increasing the stability. The thorough reaming and enlarging of the acetabulum is greatly facilitated by the semicircular reamers with a one-way cutting edge devised by Prof. Adam Gruca of Warsaw, Poland (Fig. 5). In addition to their being of various sizes, so that one can gradually increase the circumference and depth of the new acetabulum, they can be centered by means of a point or screw in the center of the reamer which enables one to increase the proportions always at the same desired angle. This is of great importance in obtaining adequate superior and anterior depth to give stability and freedom of movement of the prosthesis in the acetabulum.

The course of the prosthesis into the lateral cortex of the femur can be determined by placing the end of the index finger under the femur below the greater trochanter and sighting for the proper angle. With a quarter-inch drill, the operator should start in the center of the cancellous portion of the neck and drill through the neck at an angle of 125 to 135 degrees. For this purpose one may use a triflanged nail starter, as designed by J. Warren White, going through the cortex with only the small portion of the drill. Then a short reamer, which is the shape, size, and length of the tapered portion of the prosthesis, is inserted into this tract and the cancellous bone is reamed out to make a suitable seat for the prosthesis. All the cancellous bone that has been reamed out is collected and packed along the course which the prosthesis is to follow to stimulate further osseous growth about the prosthesis.

The bed or seat having been well prepared, the operator should hold the head of the prosthesis so that the wide part of the tapered neck (Fig. 6-A) is in line with the superior and inferior surface of the neck, and the narrow, tapered portion (Fig. 6-B) is in line with the anterior and posterior surfaces of the neck. Held in this position, the prosthesis is pushed down along the prepared tract until resistance is met in the firmer subcortical bone. The prosthesis is then impacted into the lateral cortex with a mallet applied to a wooden block, which protects the head of the prosthesis, or with a contoured impactor. The femur is replaced into the acetabulum with a skid. The tendinous fibers of the glutaeus minimus and glutaeus medius are sutured to their original insertion in the trochanter with chromic or surgilon sutures. To facilitate the approximation of these structures, the extremity is abducted by placing the knee and leg on a sterilely draped box, nine inches high, ten inches wide, and twelve inches long, placed on the lower portion of the operating table. This brings the greater trochanter closer to the muscles and does not put them under much stress while they are being sutured into their insertion. The tensor fasciae latae is shifted forward and reapproximated with interrupted sutures. The skin incision is then closed. A well padded plaster boot is applied and fixed to a posterior board with the extremity in internal rotation.

We have found that, when an adduction deformity has existed for a long time, subcutaneous tenotomy of the adductor muscles at their origin is very helpful in relieving the dominance of their pull during the initial healing period. It is our opinion that by relieving the adduction pull there is less likelihood of dislocation of the hip, which, if it occurs, proves a troublesome complication.

RESULTS

This group, operated upon between January 17 and May 17, 1950, consists of four males and eight females whose average age was seventy-four years; the youngest was sixty-four and the oldest eighty-six. Prostheses were placed in five right hips and seven left hips. Of these, six were fresh fractures of the neck of the femur; four were cases of non-union with pain and inability to bear weight for one or two years; two were cases of aseptic necrosis of the head following healed fracture of the neck. These last two patients had been treated by flanged nail six and nine years earlier, respectively. Those patients with aseptic necrosis had had pain and had not been able to walk except on crutches to move from bed to chair for over one year before operation.

There were complications in most of these patients which made the operative risk greater and the convalescence more tedious. Four had hemiplegia on the affected side; one was a severe diabetic with hypertension; two were custodial inmates of a mental institution; two had "arthritis" of both knees; and one had an ankylosed knee.

There were three deaths. One occurred thirty-six days after the operation in a male, eighty-six years old. His death, a week after discharge from the hospital, was due to exposure, resulting in pneumonia. An eighty-year-old male died almost three months after operation of numerous unfortunate complicating circumstances which used up his vitality. The third was a female, sixty-six years old, who had a hemiplegia. She died thirty-five days after the operation while sitting comfortably at home in a chair; she had had a second cerebral accident. The operation did not seem to influence the demise of any of these old people in any way.

We have followed the nine living patients for over one year. The longest follow-up was eighteen months and the shortest, twelve months. The average time since the insertion of the prosthesis was 14.4 months.

The only troublesome complication in this series was dislocation of the hip, which occurred in three cases. Two of these were in hemiplegics who had severe adductor spasm. These dislocations were reduced and the extremity was placed in internal rotation and abduction in a toe-to-knee cast, with a cross-board and foot cast on the opposite leg for three weeks; these patients had no further trouble. The third case was not a complete dislocation, but the prosthesis now rides on the upper rim of the acetabulum. This patient has a good stable gait. Since the dislocation was not discovered until several months after he went home and since he was perfectly happy with his painless hip and fair degree of motion and was able to get around with a cane, we could not prevail upon him to let anything further be done.

In this day of scarcity of hospital beds and expensive hospital care, this method of treatment for these patients with hip disabilities of long standing also has economic advantages. The average period of hospitalization for this series was thirty-one days. However, the average number of hospital days of all patients treated has been much less.

The evaluation of function is extremely difficult in a group such as this. All enjoy a measure of weight-bearing and get around to the extent that their physical strength and mental capacity permit. Three of these patients live in nursing homes and two are in mental institutions, but they enjoy getting about and helping themselves in their limited sphere of endeavor. The remaining patients live at home and take a part in household duties. Most of them still use a cane and occasionally a crutch. One (a woman eighty-one years old) works daily in her garden, weather permitting, without any support.

There are several who have some pain, but they have pain in most of their other joints as well. As has been mentioned, the first nine patients in this series were operated upon through an anterior approach to the hip and not all of the capsule was removed. These have more complaints than those in whom we used the posterolateral approach and removed the capsule. The range of motion is rather remarkable. All patients have flexion of 90 degrees and full extension, although abduction is limited by weakness of the glutaei and adductor spasm of long standing.

Most of these patients, in spite of certain functional limitations, feel that the operation has been worth while in giving them considerably more activity than they had enjoyed previously. The degree of independence following operation must be governed by their physique and ability to recover, but they feel that the increased comfort and improved function justified the procedure.

The advantages of this method are as follows:

1. It can be used in cases of old non-union, whether the neck is long or short.
2. The method is adaptable to fresh fractures which may be less likely to heal because of the age of the patient and the character of the fracture.
3. It is useful in aseptic necrosis and hypertrophic arthritis occurring in old people.
4. In those patients in whom the capsule had been removed, there was little pain and discomfort on movement or weight-bearing.
5. The patient can leave the hospital and begin weight-bearing in three or four weeks.

CONCLUSION

We realize that the last word on the subject of prostheses for the head of the femur will not be written for many years. The advent of these revolutionary suggestions represents a general revolt against fusions, osteotomies, and other defeatist attempts to meet the problem of the painful, unstable fractured hip. The enthusiasm engendered in these patients and the apparent good early results obtained by this method suggest that old people who would otherwise be incapacitated may be given a stable, useful hip which will carry their weight for the remainder of their years.

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AN END-RESULT STUDY OF VARIOUS OPERATIVE PROCEDURES FOR CORRECTING FLAT FEET IN CHILDREN *

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Stimulated by a remark of Dr. J. Albert Key that he had never been favorably impressed by the various operative procedures for correcting flat feet and, with the exception of the Kidner operation, had performed none, the authors reviewed the records of the Shriners' Hospital in St. Louis of all the cases in which surgery for flat feet had been performed.

Even in this Hospital, which averages about 400 admissions and 650 operations per year, surgery for flat feet has been performed infrequently. It is estimated that, for every patient with flat feet for whom surgery was advised, thirty to forty patients with this condition were seen for whom no treatment or conservative treatment was recommended. All patients in this series were under the age of fifteen when surgery was performed, since no patients are admitted to a Shriners' Hospital after that age.

In children two main types of flat feet are encountered. The first is the flaccid flat foot ("weak foot") in which a longitudinal arch is present without weight-bearing but collapses when weight is applied to the foot; the second is the spastic flat foot or foot held in spastic eversion. Flat feet or pes planus due to poliomyelitis or to cerebral palsy are not included in this series, nor are congenital equinovalgus deformities.

Flaccid flat feet in children are of rather frequent occurrence and, in the great majority of cases, are completely asymptomatic. Surgery should almost never be considered in these cases. However, a small number of these patients are benefited by operation. They are the children who have flat, pronated feet with rocker bottoms, who walk with a plodding gait, and are reluctant to run if they can walk, or walk if they can ride, and complain of pain in their feet. It was this type of case for which surgery was advised as well as the cases of spastic flat feet.

Most of these patients had already been fitted with corrective shoes, arch supports, or Thomas heels before being seen in the Clinic at the Shriners' Hospital. Others were treated with conservative measures at the Shriners' Hospital before surgical correction was recommended.

The records of the fifty-three children on whom operations had been performed for the relief of painful flat feet were reviewed. Only four of these were unilateral, the other forty-nine being bilateral. Thus there were 102 feet, on which 111 surgical procedures were performed. Spastic eversion was present in seventeen feet; the remaining eighty-five were weak, relaxed, or pronated feet of congenital origin. Sex incidence was almost equal, with twenty-six males and twenty-seven females. Köhler's disease was present in seven and accessory navicular bones in eleven feet.

The youngest child was eight years of age at the time of operation; the average age was twelve years.

The follow-up information in this report was obtained by analysis of charts, by personal examination of available cases, and by questionnaires.

In classifying the end results after operation, we have used the following categories: "excellent", "good", "fair", and "poor".

An "excellent" result is one in which the foot is asymptomatic on normal activity and on exertion, in which there is a satisfactory longitudinal arch, without valgus or varus of the tarsus, and the patient wears standard shoes comfortably.

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* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 30, 1951.

A "good" result is one in which there is not more than a first-degree pes planus, there is not more than a minimal amount of valgus or varus in the tarsus, and the patient can wear standard shoes without correction or supports comfortably.

A "fair" result is one in which mild symptoms may be present, but not enough to limit normal activity or occupation. More than first-degree pes planus may be present, as well as more than a minimal amount of valgus in the tarsus. The patient may have to wear arch supports or corrective shoes.

A "poor" result is one in which symptoms in the feet are the same as before the operation or worse and activity and occupation are limited. In some instances it has been necessary to lower the classification of a given case because follow-up x-rays failed to show complete bony ankylosis of the tarsal joint or joints operated upon, even though symptoms were not present. In these cases, very firm fibrous ankylosis must have occurred in the absence of solid bony union.

The first operation for flat feet done at this hospital was an arthrodesis of the talonavicular and naviculo-cuneiform joints, done by Dr. Leroy C. Abbott in 1927, who used a medial approach. This operation was performed fifteen times between 1927 and 1935 and was accompanied by heel-cord lengthening in five instances. Average follow-up on these fifteen cases was nine and one-half years. The results showed that three of the feet (20 per cent.) were considered excellent; eight (53 per cent.) good; two (13 per cent.) fair;

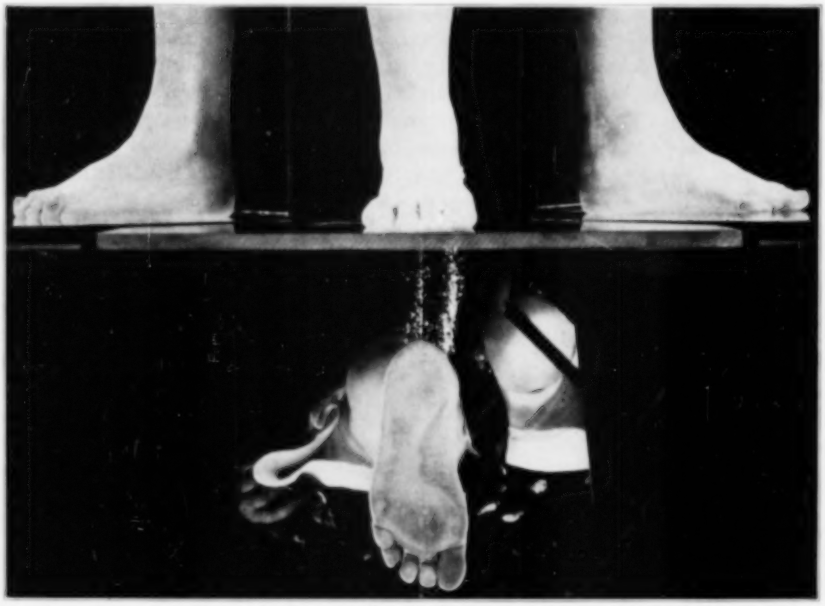

FIG. 1-A*

Case 1. Arthrodesis of the talonavicular and naviculo-cuneiform joints.

Painful flat feet had been present for three years. In 1927, at ten years of age, bilateral operations had been performed. Heel cords had been lengthened later. These photographs (Figs. 1-A and 1-B) and x-rays (Fig. 1-C) were made in 1950, twenty-three years after operation. The right foot was rated excellent; the left, good. (See text for case report.)

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* All the follow-up photographs were made with the patient bearing full weight on a slab of plate glass with mirrors placed to show right and left lateral views and a plantar view according to the technique of Lovett. The lateral x-rays were made with the patient bearing full weight. In all the x-rays the right foot is on the reader's left and the left foot is at his right.

and two (13 per cent.) poor. In the two with poor results, a second operation was necessary. Since the results were satisfactory in eleven (73 per cent.) of the fifteen feet, this must be termed a fairly satisfactory operation.

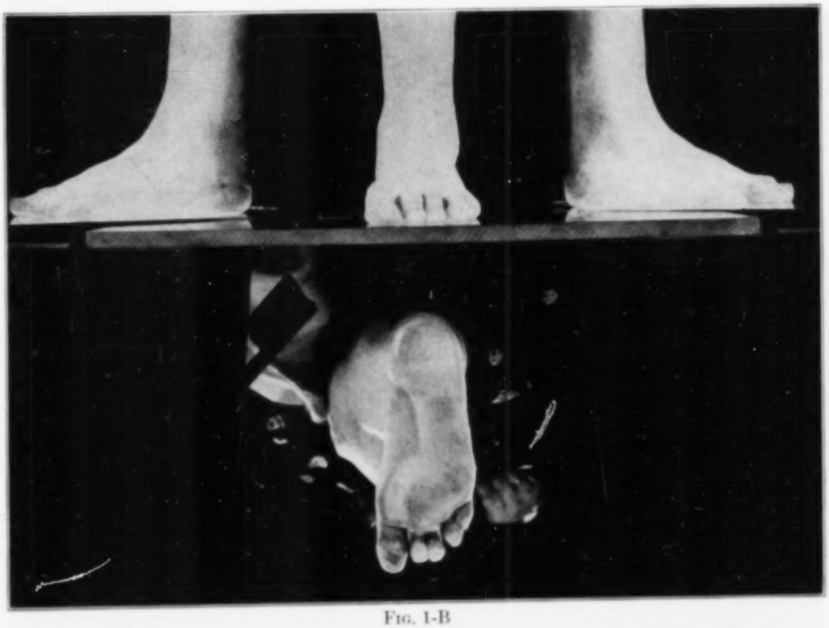

Fig. 1-B

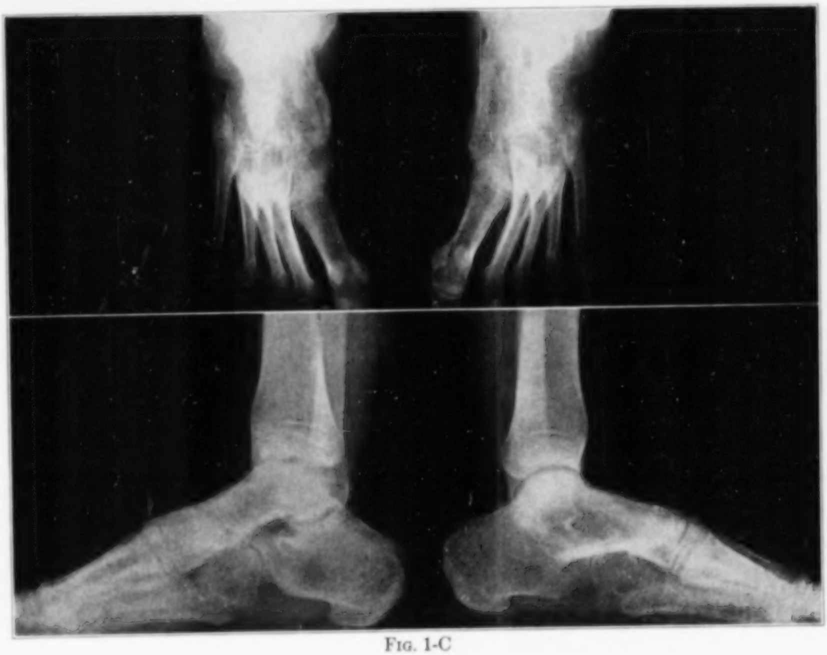

Fig. 1-C

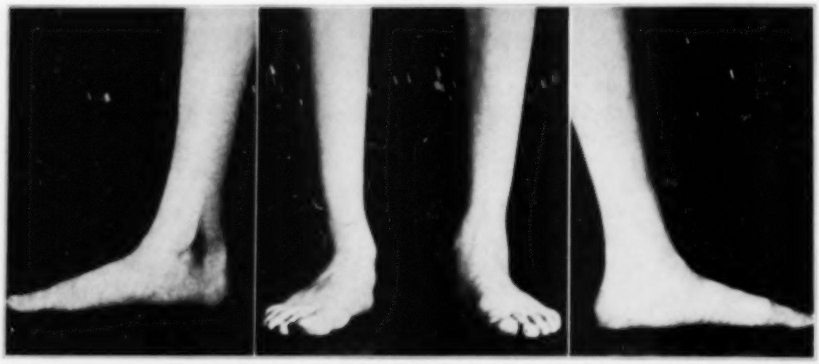

FIG. 2-A

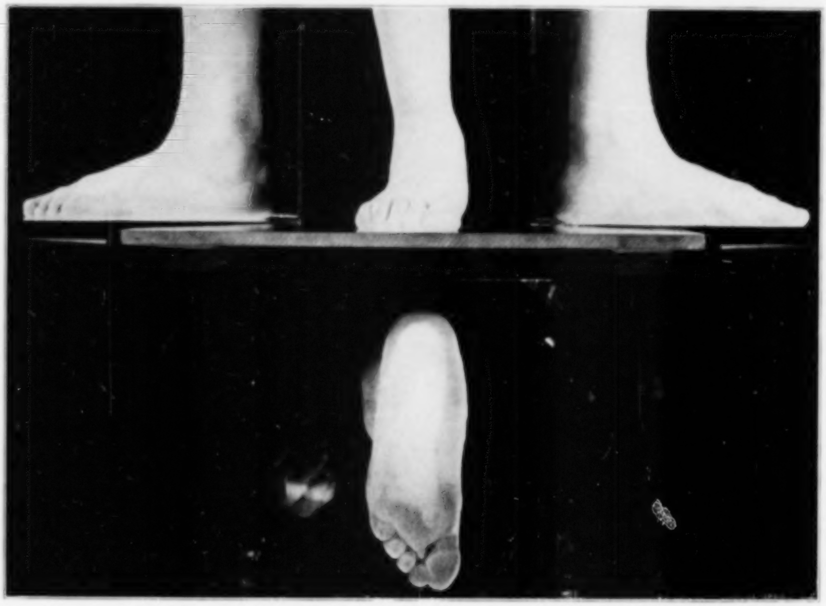

FIG. 2-B

Case 2. Bilateral Hoke flat-foot operations.

Fig. 2-A shows the condition of the feet before operations, after eight years of conservative treatment.

Figs. 2-B and 2-C are weight-bearing, multi-angle photographs of the feet taken in 1950. Operations had been performed in 1931 at the age of thirteen.

Fig. 2-D shows x-rays made at the same time. The result was rated as poor. (See text for case report.)

The true Hoke flat-foot operation consists of arthrodesis of the naviculo-cuneiform joint, a small wedge with its base medial and inferior being removed. A small cortical graft is inserted in a prepared slot in the two bones. This was done in nine feet, and the average follow-up was nine and one-half years. In only two cases were the results considered good, while seven were classed as poor. Of the seven feet with poor results, five had to be operated on again because of continued pain. It is concluded that fusion of this one joint in a relaxed flat foot is not sufficient to support a flattened longitudinal arch, nor does it correct the valgus back portion of the foot in a flaccid or spastic flat foot. This operation was abandoned after 1934.

In this same year the first so-called "double arthrodesis" of this series was performed. This consisted of an arthrodesis of the subtalar and the talonavicular joints in which

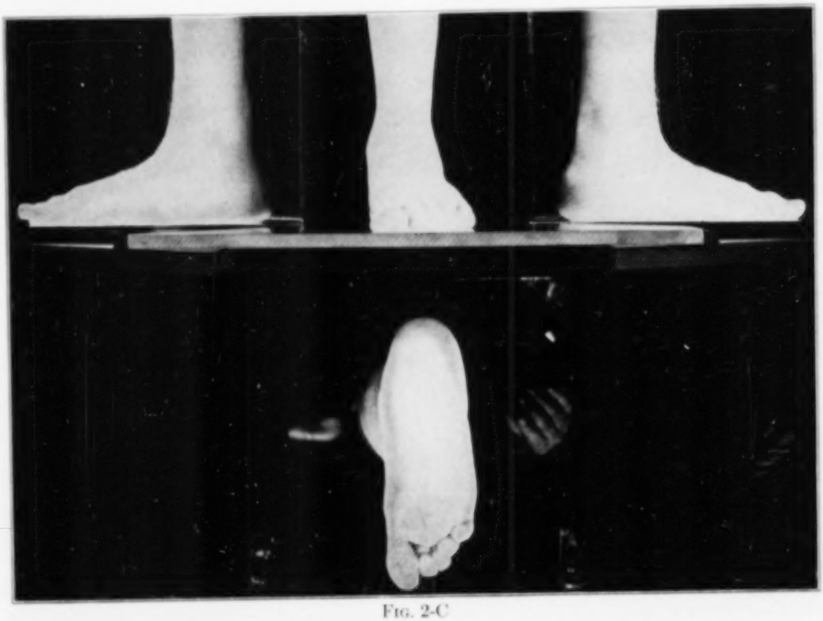

FIG. 2-C

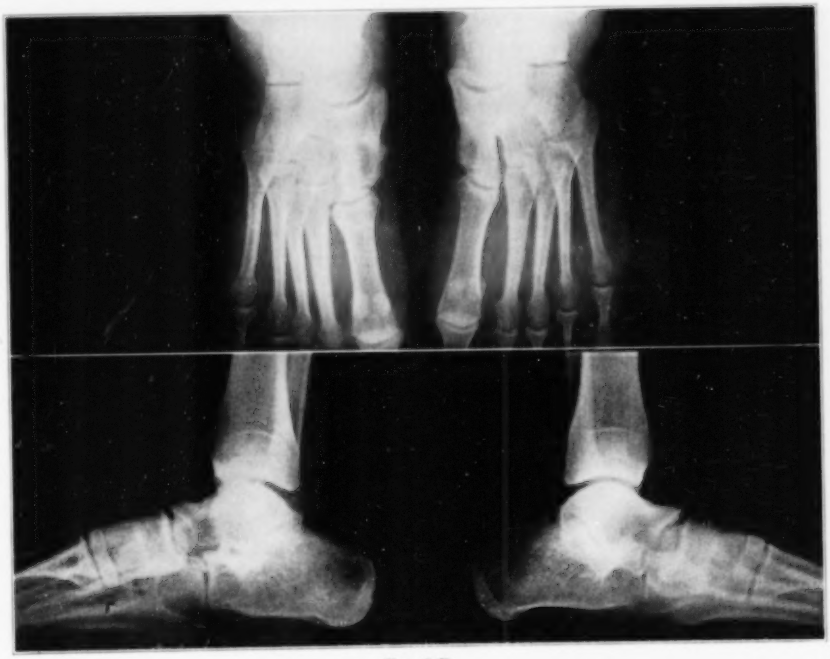

FIG. 2-D

an approach through the medial side of the foot was used. It was used on twenty-four feet during the ten years from 1934 to 1944. Section of the peroneals was carried out on six feet, and the heel cords were lengthened twice. This proved to be a satisfactory opera-

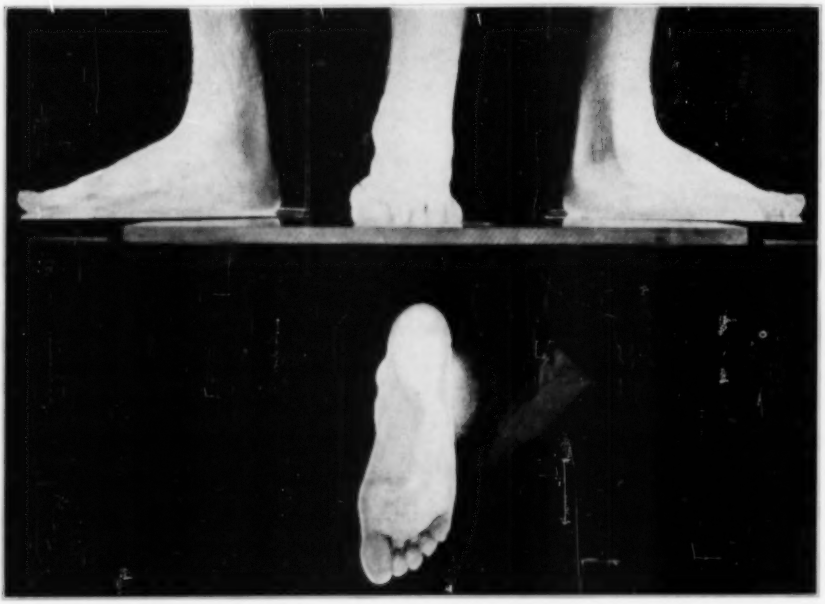

FIG. 3-A

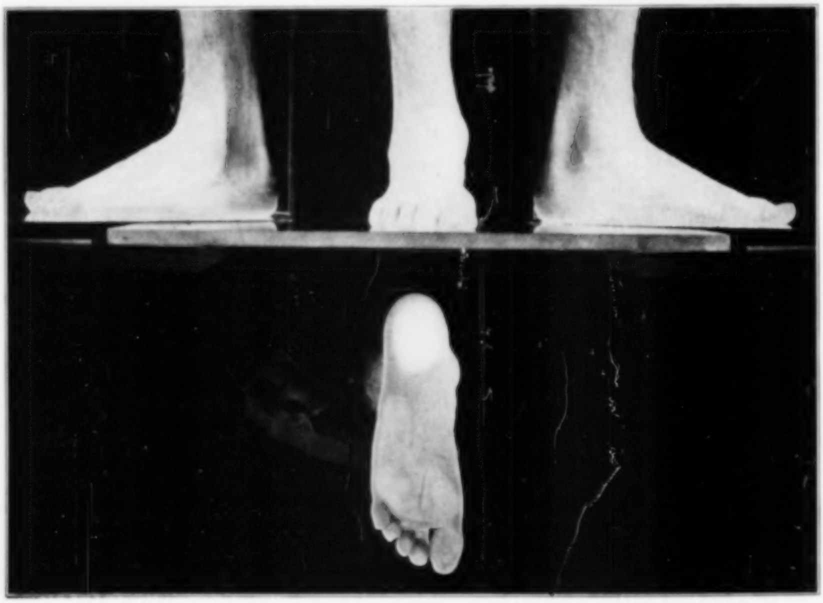

FIG. 3-B

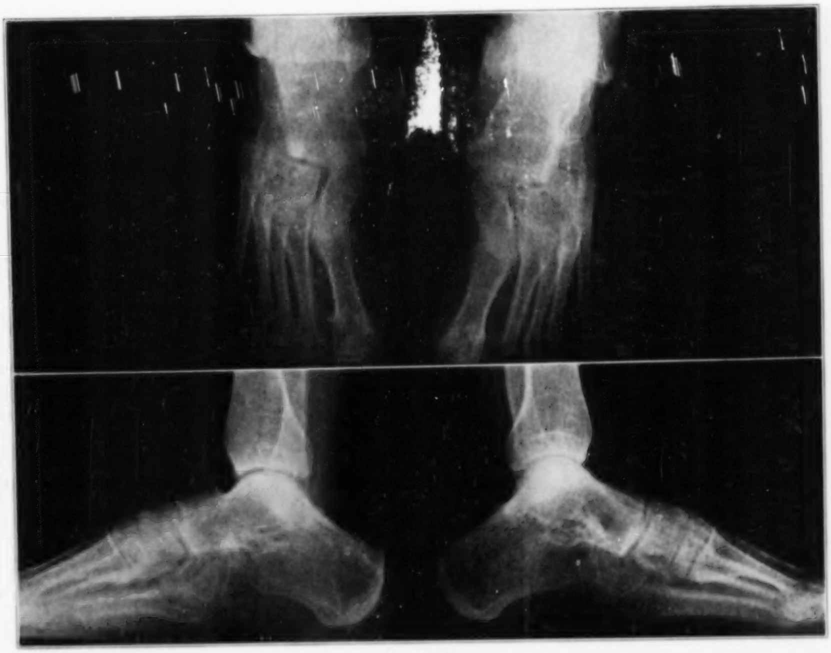

Fig. 3-C

Case 3. "Double arthrodesis" had been performed in 1936.

The patient served six years in the Infantry during World War II without symptoms. Weight-bearing photographs were made in 1950 (Figs. 3-A and 3-B) as were x-rays (Fig. 3-C). Both feet were rated excellent. (See text for case report.)

tion. The results in nine (37.5 per cent.) were considered excellent, in ten (42 per cent.) good, in three (12.5 per cent.) fair, and in two (8 per cent.) poor. The average follow-up was five and one-half years. From these results one gets the impression that, if a flat foot is to be corrected permanently by an arthrodesing procedure, the two joints which certainly should be included are the subtalar and the talonavicular.

In 1931 the first so-called "modified Hoke" flat-foot operation was carried out. This consisted in exposing the medial side of the navicular and the joints on either side of it through a medial approach. The Kidner operation was then done, removing an accessory navicular when present or removing the navicular tuberosity if it were prominent, thus leaving the posterior tibial tendon free to be attached at the inferior surface of the navicular prior to closure of the wound. Next, the naviculo-cuneiform joint was denuded of cartilage (the original Hoke flat-foot operation); in addition, cartilage was removed from the talonavicular joint and from the sustentaculum tali which was exposed from the same medial approach. This operation was performed twenty-seven times in the next seventeen years. The average follow-up was five years. Five feet were considered excellent (18.5 per cent.); nine (33.3 per cent.) good; twelve (44.4 per cent.) only fair; and one (3.8 per cent.) a failure. In this last case a second operation was done. We believe that the so-called modified Hoke operation would have been more successful had the entire subtalar joint been fused instead of only the sustentaculum tali.

The standard Hoke triple arthrodesis was used on twenty-six feet for correction of a flat-foot deformity, the first one being done in 1935. Either a medial or lateral approach to the three joints may be used. With the medial approach, exposure of the calcaneocuboid joint is difficult. However, we think this disadvantage is outweighed by the inability to

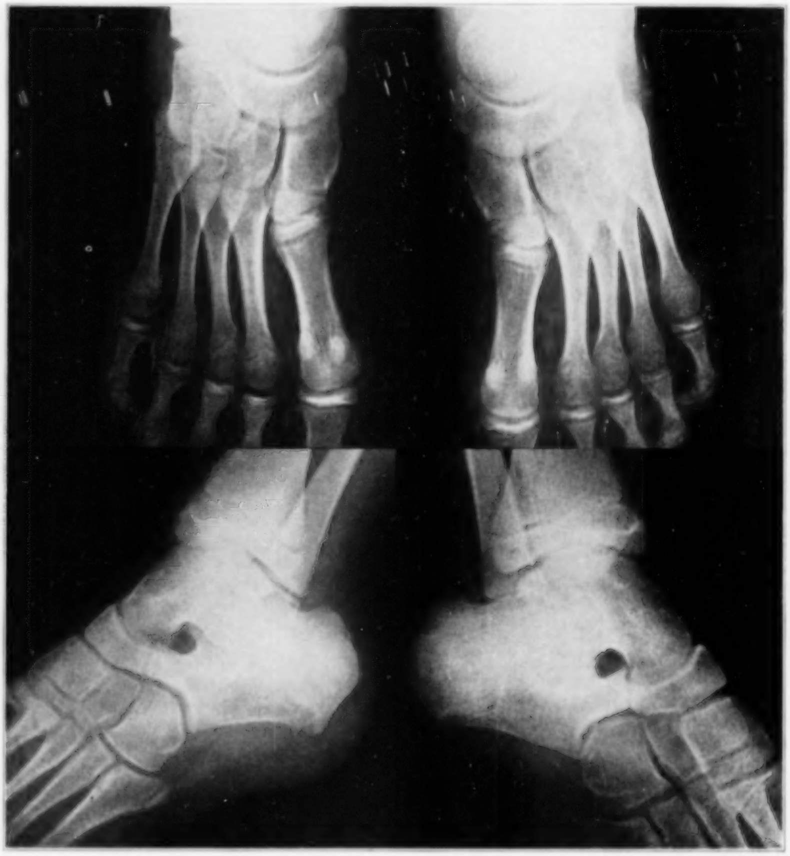

FIG. 4-A

Case 6. Modified Hoke operation.

Fig. 4-A shows the preoperative x-rays. In 1946, operation was performed. Photographs of the feet (Figs. 4-B and 4-C) and x-rays (Fig. 4-D) were made in 1950. (See text for case report.)

remove an accessory navicular or a large navicular tuberosity when a lateral approach is used. Moreover it is hard to remove the proper wedges of bone from the subtalar and talonavicular joints when the lateral approach is chosen. The average follow-up of these twenty-six cases was five years. Fourteen (54 per cent.) were considered excellent, six (23 per cent.) good, four (15 per cent.) fair, and two (8 per cent.) poor. The two patients with poor results underwent further surgery at a later date. With 77 per cent. satisfactory results, we disagree with Campbell's text which advises against using a triple arthrodesis for correction of flat feet.

In the eight remaining cases in this series various types of procedures were used. The operation described by Young in 1939 was performed in six of them. This involved shifting the mobilized tendon of the anterior tibial into a groove prepared in the navicular and the posterior tibial tendon into a similar groove made on the plantar surface of the same bone. The average follow-up in these six cases was five and one-half years with four rated excellent and two good. This procedure seemed to produce over-correction with inversion of the foot, but this gradually corrected itself with active use. After several years, one foot is thought to show evidence of loss of correction.

In another case the operation described by Voshell was used. This consisted in the insertion of an iliac-bone graft between the os calcis and the neck of the talus. Although a good result was obtained in the right foot, painful spastic eversion developed in the left, necessitating a triple arthrodesis.

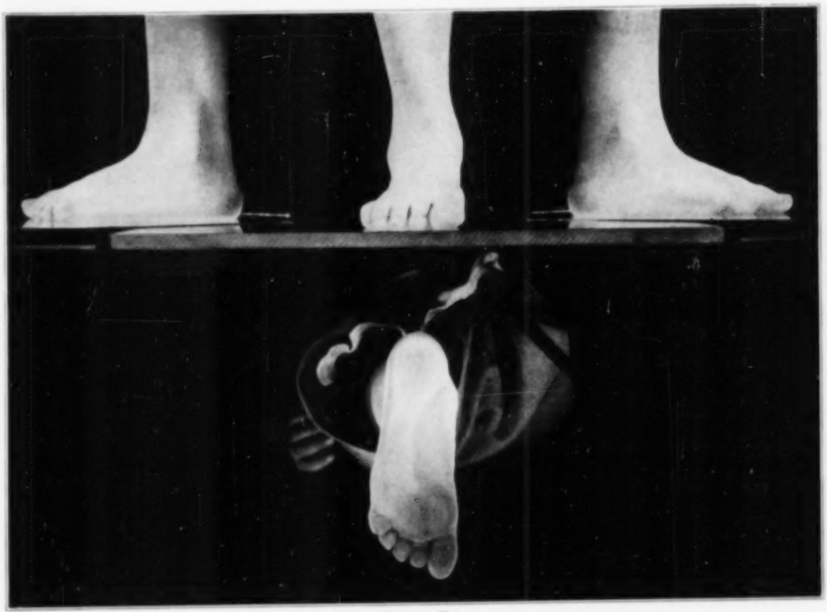

Fig. 4-B

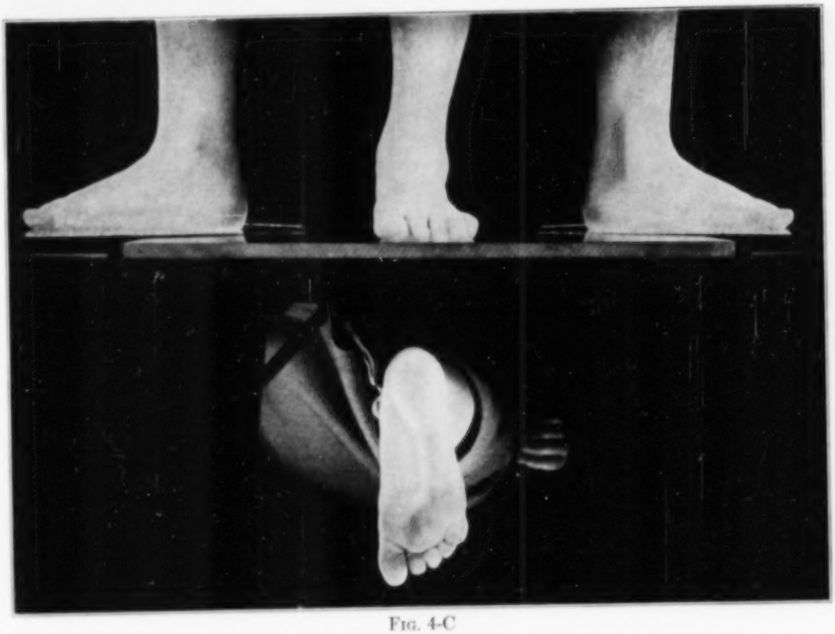

Fig. 4-C

Another case of spastic flat-foot was treated by manipulation under anaesthesia, section of the peroneals, and plaster fixation in inversion. Follow-up one year later showed freedom from pain but no correction of deformity.

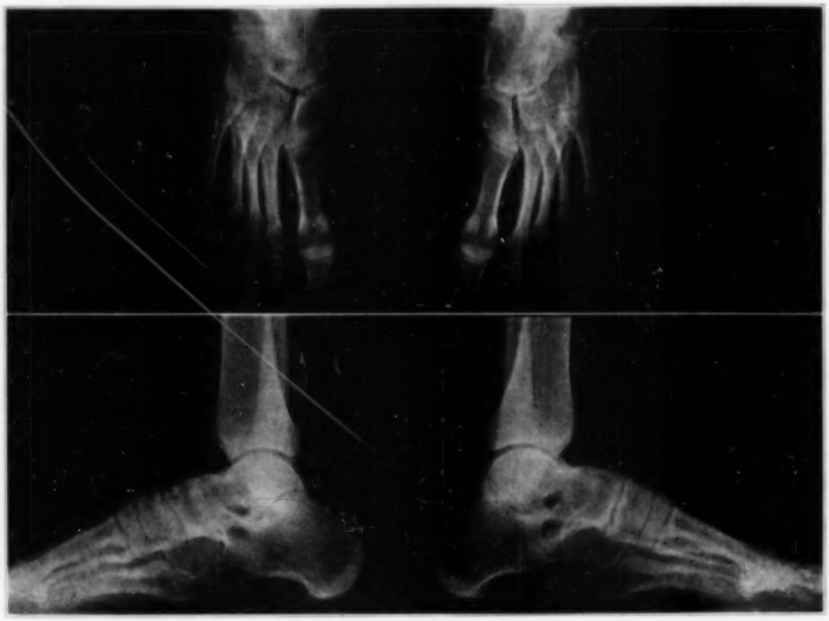

Fig. 4-D

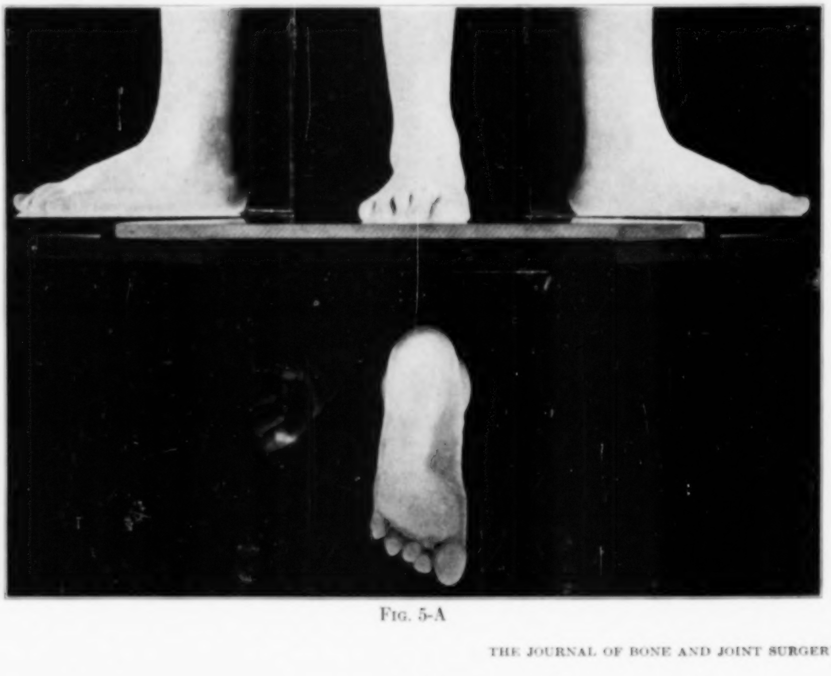

Fig. 5-A

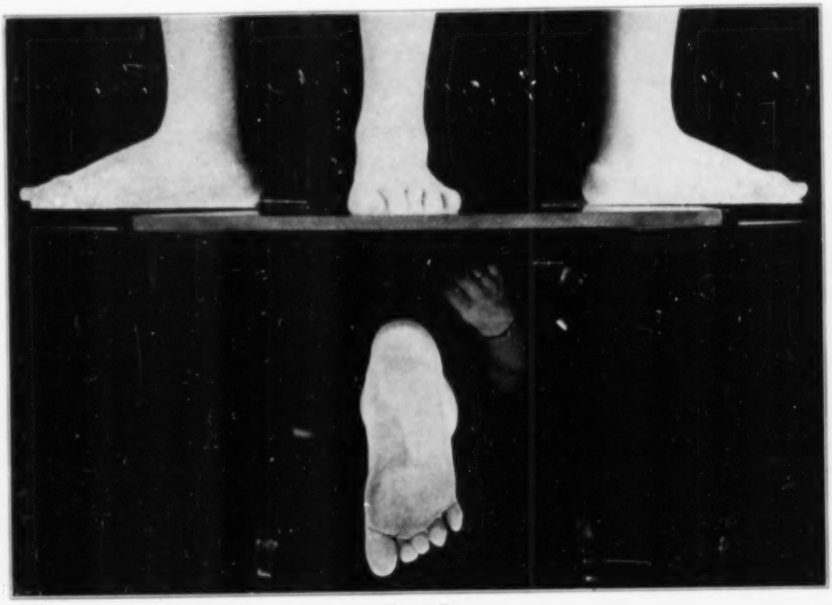

FIG. 5-B

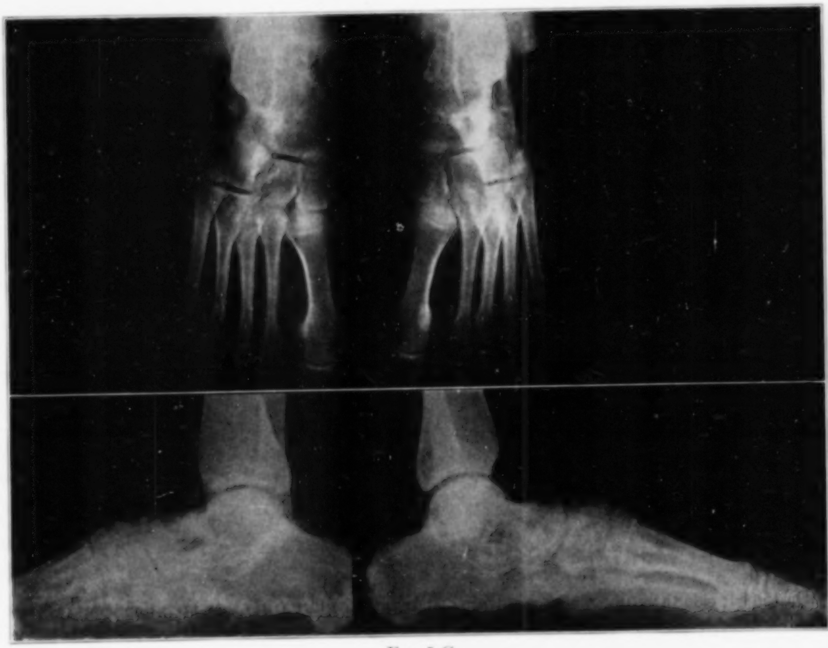

FIG. 5-C

Case 7. Triple arthrodesis.

In 1944 at the age of fourteen, bilateral triple arthrodeses had been performed.

Fig. 5-A shows the result on the right and Fig. 5-B the result on the left in 1950, six years after operation. X-rays (Fig. 5-C) were made at the same time. (See text for case report.)

In evaluating these results, it should be stressed that the unsatisfactory results were not necessarily due to the procedure, but may well have been the result of faulty operative technique or postoperative management in some instances.

CASE REPORTS

Case 1. W. D., No. D-197. This is the first patient operated on by Dr. Abbott in 1927. She was first seen that year with a history of painful flat feet, worse on the left, of three years' duration. After bilateral talonavicular and naviculo-cuneiform arthrodeses with tibial grafts, the heel cords were lengthened.

When examined in 1950, she had no complaints except for callosities on each heel (Figs. 1-A and 1-B). Good longitudinal arches were present, the left being slightly higher than the right. The tarsus of the left foot was in slight eversion. There was no active inversion or eversion of either foot. The woman weighed 196 pounds and stated that she was an active housewife and mother.

X-rays (Fig. 1-C) showed fusion of each talonavicular and naviculo-cuneiform joint. On the left in addition there was fusion between the talus and os calcis through the sustentaculum. The right foot was rated excellent, the left as good because of slight overcorrection.

Case 2. H. B., No. H-57. This patient was followed in the Clinic for eight years because of painful flat feet with short heel cords. In adolescence peroneal spasm developed (Fig. 2-A). In 1931, at thirteen years of age, bilateral naviculo-cuneiform arthrodeses (Hoke flat-foot operations) were done, grafts from the fibula being used. In addition, section of peroneals and heel-cord lengthenings were performed.

When examined in 1950, nineteen years later, he was working as a machinist, wearing arch supports and high shoes at work. He complained of occasional aching and a tired feeling in his feet. He had played minor league baseball, but couldn't run fast enough. He now weighed 225 pounds.

Examination showed third degree flat feet. Both feet were semirigid with limited inversion and eversion (Figs. 2-B and 2-C). X-rays showed solid naviculo-cuneiform fusion on each side (Fig. 2-D). Collapse of the long arches and spurring of the talonavicular joints were present.

This case was rated as a poor result bilaterally.

Case 3. W. B., No. M-133. This patient was first seen three months after the onset of painful eversion of both feet with collapse of the longitudinal arches. This had developed after an injury in which he sustained a fracture of the third lumbar vertebra.

In 1936, at thirteen years of age, bilateral subtalar and talonavicular arthrodeses ("double arthrodesis") were performed.

He served in the Infantry in World War II without symptoms referable to his feet. No examiner in the Army ever detected any abnormality. When examined in 1950 he had good longitudinal arches, but no inversion or eversion of either foot. There was slight abnormal motion in both the ankle and mid-tarsal joints bilaterally.

X-rays showed fusion of the joints which had been operated upon. Both feet were graded as excellent.

Case 4. F. H., No. O-176. This patient had long, thin, flat, pronated feet. At the age of thirteen, in 1938, a modified Hoke operation was performed bilaterally.

When examined in 1950, he stated he had served in the Navy for two years without difficulty. He had played amateur basketball and had worked as a carpenter without foot symptoms.

He had satisfactory longitudinal arches in both feet and each tarsus was in neutral position. X-rays showed that the right naviculo-cuneiform joint was not fused.

The right foot was rated as good and the left as excellent.

Case 5. W. G., No. S-51. When this patient was first seen at the age of twelve, he had had painful pronated feet for eight years. In 1942, at thirteen years of age, bilateral modified Hoke operations were performed.

When examined in 1950 he complained of occasional pain in his feet. He had been forced to quit a job as a laborer because of this. However, at that time he was working as a mail sorter. There was a slight pes planus of the right foot with slight pronation and callosities under the second and third metatarsal heads. Hammer toes were present.

On the left side there was a very slight pes planus with the tarsus in neutral position.

X-rays showed bilateral fusion of both naviculo-cuneiform joints, with subtalar fusion on the left. Fusion had not occurred between the talus and navicular on either side. In spite of the x-rays, the right was rated as fair and the left as good.

Case 6. J. K., No. W-99. This girl was first seen at the age of twelve with a history of spastic flat-foot on the left of three months' duration. Congenital flat-foot was found on examination with bilateral calcaneonavicular bars. In 1946 a modified Hoke operation was performed on each side consisting of fusion of the talonavicular and naviculo-cuneiform joints as well as of the sustentaculum tali to the talus.

When examined in 1950, four years later, she stated that she had no difficulty with her feet except for occasional aching in cold weather. Both feet showed satisfactory longitudinal arches with the tarsus of each foot in neutral position.

X-rays of each foot showed satisfactory subtalar and talonavicular fusions, but fibrous ankylosis of each naviculo-cuneiform joint. In spite of this both feet were graded as excellent.

Case 7. M. S., No. I-239. This girl was first seen in the Clinic at the age of two years because of flat feet and bowed tibiae. In 1944, at the age of fourteen after she had suffered from painful feet for nine years, bilateral triple arthrodeses were performed through lateral incisions.

When examined in 1950, six years later, she complained of occasional pain in her feet with changes in the weather, but of none with ordinary activity. There was second-degree pes planus of the right foot with moderate pronation, and first-degree pes planus of the left side also with moderate pronation.

X-rays showed fusion of all six joints operated upon and a medial prominence of the tuberosity of each navicular. The right foot was rated as fair and the left as good.

Case 8. J. B., No. R-144. This patient was first seen in the Clinic with a three-year history of painful flat, everted feet. In 1941 bilateral triple arthrodeses had been performed. In 1945, because of hammer-toe deformities, the distal one-half of each second toe had been amputated.

At follow-up examination in 1950, he stated that he had occasional slight pain in each foot after long hikes. Slight pes planus was present bilaterally and, as a result of the amputations of the second toes, hallux valgus was developing bilaterally.

X-rays showed solid fusion of the six joints which had been operated upon and more flattening than was apparent clinically. Each foot was considered good.

SUMMARY AND CONCLUSIONS

1. The results of 111 operative procedures of various types for flat-foot, which were performed on fifty-three children, eight to fifteen years of age, are reviewed.

2. In no case should an arthrodesing operation for flat-foot ever be done for cosmetic reasons only.

3. These procedures should be reserved for the relief of disabling pain and then only after exhausting every means of conservative therapy.

4. The surgeon, the patient, and the parents must be willing to exchange a loss of inversion and eversion for the relief of pain and disability.

5. Through trial and error, we have found that, although the earlier procedure of arthrodesing the talonavicular and naviculo-cuneiform joints was fairly satisfactory, arthrodesing operations for relieving painful flat-foot in children are most successful when the subtalar joint is included.

TRANSPLANTATION OF THE SEMITENDINOSUS FOR REPAIR OF LACERATION OF MEDIAL COLLATERAL LIGAMENT OF THE KNEE *

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Development of an operative procedure, such as this, does not spring full-blown from advance plans later executed. Though, as we later found, transplantation of the divided semitendinosus to replace the medial collateral ligament had long previously been done, that method had no bearing on the development of the present procedure. Transplantation of the intact semitendinosus developed by chance and on the basis of previous operative procedure reported by us of total excision of the medial meniscus through single-skin, double-capsule incision.[1] We have reported, as have others, repair of the medial collateral ligament with fascia lata transplants.[2] Such repairs with fascia, while often efficient in fresh injuries due to the stability provided while repair or reattachment of collateral ligament structure itself occurs, have not in our hands proved satisfactory for the old lacerations. Fascial repair requires considerable surgery both in the securing of the fascia and in the damage to the medial femoral condyle and tibial tuberosity for its implantation and fixation.

The first time we used this procedure was in January 1950.

A man, fifty-one years old, was admitted, who had slipped four days before so that both legs were spread widely apart, markedly abducting his knees. He had had severe pain in the medial side of both knees. Marked swelling of the right knee had occurred and a physician had aspirated blood out of the knee on two occasions with recurrence of swelling despite elastoplast bandage.

On examination, the right knee showed motion only from 180 to 160 degrees with marked hemarthrosis. Because of the considerable swelling and pain, relaxation of the medial collateral ligament could not be demonstrated. Roentgenograms were negative for pathological changes in bone.

Cold compresses were used for forty-eight hours and complete bed rest was continued for two weeks. Because of an early temperature rise, crysticillin was given with subsequent reduction of temperature.

Two weeks following admission, definite relaxation of the medial collateral ligament of the right knee was present. Motion had increased; the range was from 180 to 80 degrees. Swelling was markedly reduced. Generalized tenderness over the medial meniscus area and the medial collateral ligament was present.

Two and a half weeks after injury, arthrotomy was done. Though no relaxation of the cruciate ligaments could be determined preoperatively, as soon as the patient was under anaesthesia, considerable relaxation of the anterior cruciate ligament and complete laceration of the medial collateral ligament could be demonstrated.

Arthrotomy was performed with the usual single-skin and double-capsule incision; the complete medial meniscus was removed intact, though its basilar attachment was markedly relaxed. Complete laceration with fibrillation of the medial collateral ligament was found. Synovial reflection over the anterior cruciate ligament was intact, but relaxation of the cruciate ligament was verified.

During the operation, as at previous similar operations for excision of the medial meniscus, dissection between the superficial and deep fascia posteriorly for the second capsule incision exposed the semitendinosus to palpation. The idea then occurred for its transplantation, without division of the tendon from the muscle, to replace the fibrillated, lacerated medial collateral ligament. This was carried out in a manner since used and herewith described.

Following the operation, a pillow splint was applied. The pillow spint and sutures were removed in one week. The patient was then permitted weight-bearing on crutches; this was continued for two weeks. He returned to work as a chief engineer at a hotel in one month, despite the fact that he had compensation benefits.

He was the first of the series of cases in which this procedure has been used and he was hospitalized the longest period of time, sixteen days. After one month the motion was from 180 to 110 degrees. At the present time the medial collateral ligament is perfectly stable in extension and flexion. Motion shows limitation of flexion of 20 degrees; gait is normal.

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* Read at meeting of the Orthopaedic Section, New York Academy of Medicine, May 18, 1951.

THE OPERATIVE PROCEDURE

Through an oblique anteromedial skin incision, dissection is carried down to the deep fascia. The anterior incision is made through the deep fascia and capsule; the synovium is opened proximal to the meniscus. This incision is extended, entering the synovium distal to the meniscus. The anterior end of the meniscus is freed with curved scissors, and the body of the meniscus lying beneath the collateral ligament is similarly freed according to previous report. The posterior capsule incision is made behind the medial collateral ligament or its remnants, and the posterior horn of the medial meniscus is freed from its attachment. The entire meniscus is removed. By blunt dissection the skin and fat are dissected off the deep fascia to expose the tendons of the sartorius, gracilis, and semitendinosus posterior to the posterior capsule incision. Usually the skin-fascia incision is not long enough for total visualization of these structures. Extension of the incision for this purpose is unnecessary. The semitendinosus can be clearly palpated as a firm cord posterior to the other structures and can be picked up on a loop and drawn forward by blunt dissection. Blunt dissection may be carried distally as far as desired, but proximally is arrested with firm resistance along its anterior margin. Further dissection at this point should be avoided for reasons to be seen. A triangular osteotomy of the overlying fascial, periosteal, and cortical structures, with the base of the triangle on a line parallel with the medial collateral ligament and the apex anterior, is carried out with thin osteotomes. The intact semitendinosus (at this point entirely tendon) is drawn forward and implanted beneath this triangle of fascia, periosteum, and cortical bone. Considerable tension is necessary in order to draw the tendon forward; but, if the defect in the medial femoral condyle has been properly cut and its base has not been broken off, a trap is present in which the tendon is firmly held, even before the triangular flap is drawn forward over it and reaffixed to hold it. At this time, if dissection is carefully carried upward along the tendon, it will be found that the saphenous nerve is emerging from between the sartorius and gracilis at the upper angle of the wound, and that it is this which is preventing further dissection proximally. It was in order not to divide the saphenous nerve that we previously directed that the dissection be not radically extended upward in front of the semitendinosus. The implantation of the semitendinosus tendon with its forward displacement will have been found to have closed the posterior capsule incision into the knee joint. The anterior capsule and the skin and fat are closed and such support is applied as the surgeon desires.

If one cares to perform the operation upon a cadaver, several fortuitous facts will appear (Figs. 2-A and 2-B). To determine the actual mechanism and direction of pull of the transplanted intact semitendinosus, the fat, fascia, saphenous nerve, and vein, and sartorius and gracilis attachments may be removed. Thereupon one will see that the semitendinosus fans out in its attachment to the tibia and posteriorly merges with the deep fascia of the leg. The actual tendinous inscription goes forward and finally ends distally in the periosteum beyond the tibial tubercle. In other words, the reconstructed medial collateral ligment consists of an attachment above at the medial femoral epicondyle, fanning out below to its final attachment. At the tibial tuberosity and femoral condyle rim, it is free to glide as the knee flexes and extends. Through attachments of the tendon distally, support is given both anteriorly and posteriorly to the mid-point of the articular surface of the medial tibial tuberosity. This provides free gliding motion of the tibial and femoral articulations about each other with strong medial support throughout the range of motion. The strong medial support remains present both in flexion and in extension. With the intact musculotendinous apparatus in place, the continued muscle tone provides for continuous tautness in the tendon from the tibia to the medial femoral epicondyle, until firm attachment occurs in its femoral bed. If such attachment does not become firm and the tendon continues to glide, continued stability and tautness of the new medial collateral ligament structure is still provided.

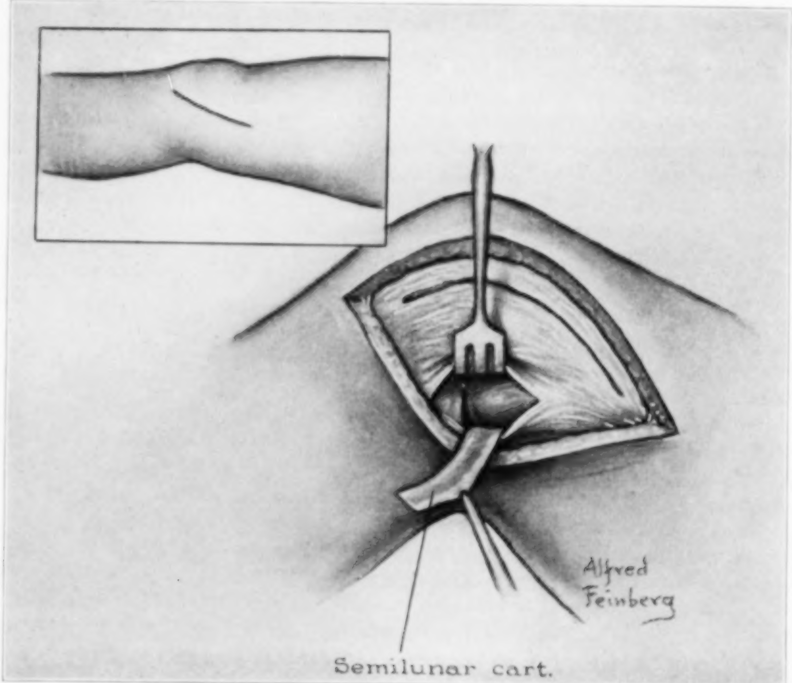
Alfred Feinberg
Semilunar cart.

FIG. 1-A

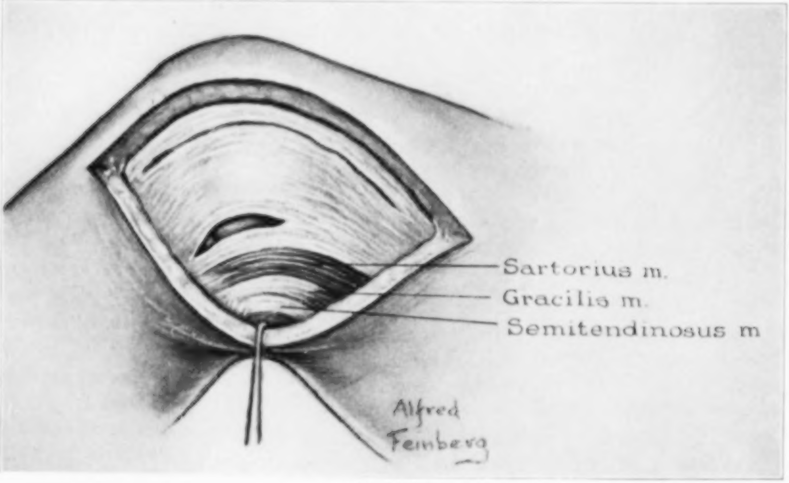
Sartorius m.
Gracilis m.
Semitendinosus m
Alfred Feinberg

FIG. 1-B

STATISTICS

Ten patients have undergone this operation. The first operation was done on January 11, 1950. There were nine males and one female; all patients were very active. Only two were over forty years of age. Both of these were laborers, ages fifty-one and fifty-two. A severe twisting injury was recorded in every instance. Two had undergone previous

Fig. 1-A: Skin incision and usual double-capsule incisions for complete removal of medial meniscus.

Fig. 1-B: Location of sartorius, gracilis, and semitendinosus. Skin and superficial fascia retracted with saphenous nerve and vein. Double-capsule incisions present following removal of meniscus.

Fig. 1-C: Triangular flap of fascia, periosteum, and cortical bone being raised with osteotomes at point of medial femoral epicondyle. Semitendinosus has been secured in a loop and retracted.

Fig. 1-D: Semitendinosus drawn forward and transplanted beneath the triangular flap. In its lower portion it is in the same alignment and position as the medial collateral ligament. Saphenous vein and nerve are shown. The nerve is seen emerging between the gracilis and the sartorius in the upper end of the incision.

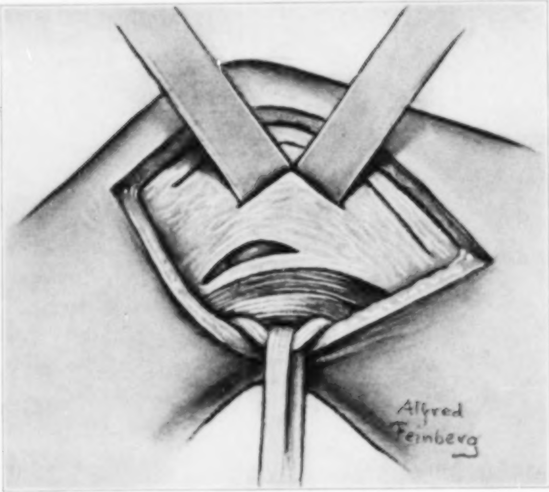

FIG. 1-C

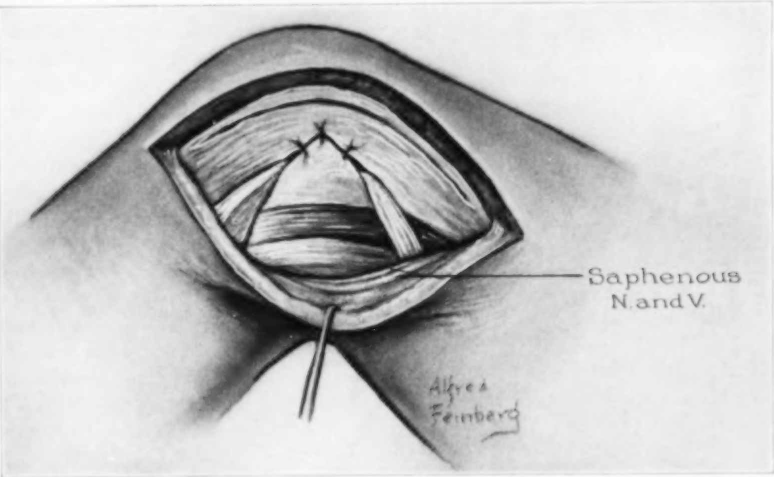

FIG. 1-D

surgery,—one had had an incomplete removal of the medial meniscus on the same knee and the other a total removal of the medial meniscus with division of the medial collateral ligament at that operative procedure. An apparent attempted repair by imbrication of collateral ligament substance had been done, but with total failure. All had had extensive conservative care. This included diathermy, external radiant heat, massage, support with plaster cylinder, knee cage, splints, and braces, but with recurring or continuing symptoms. The longest period of disability was five years, and the shortest three weeks. The average period between injury and repair of the medial collateral ligament was twenty months. In only two of the ten patients was relaxation of the medial collateral ligament clearly shown preoperatively. Two others had record of some tenderness of the medial collateral ligament area, but without relaxation. Cruciate ligamentous relaxation was noted preoperatively in two of the ten cases.

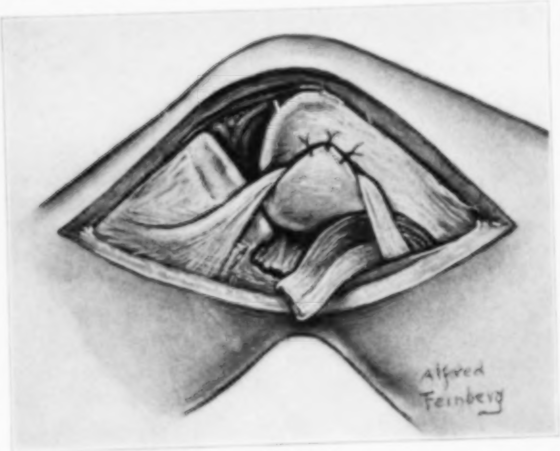

Fig. 2-A

Knee in flexion. Attachments of gracilis and sartorius have been divided to expose the fanning out of the tibial attachment of the semitendinosus, the main tendinous inscription extending forward to the periosteum distal to the tibial tubercle and the thinner portion extending backward to the fascia of the leg and the periosteum on the posterior aspect of the upper portion of the tibia.

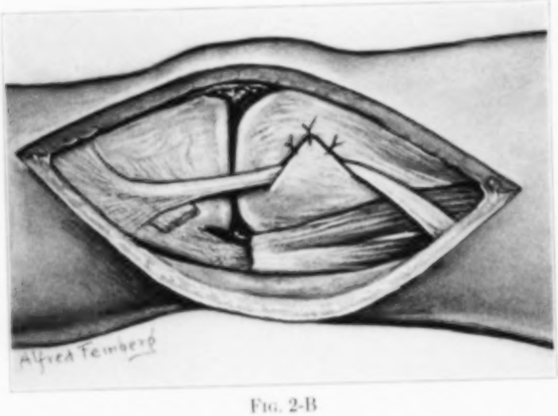

Fig. 2-B

Knee in extension. Note that the newly constructed ligament represented by the distal portion of the semitendinosus remains in the same position as the collateral ligament, whether the knee is flexed or extended. The new ligament is held taut by the intact muscle.

At operation, five patients had laceration of the medial meniscus and four others had relaxation of the attachment of the meniscus at its base. All ten patients had severe lacerations or avulsions of the medial collateral ligament and all except one were beyond the period at which spontaneous repair of these structures could be expected. Four had varying amounts of relaxation or partial laceration of the cruciate ligaments. Complete laceration or avulsion of cruciate ligaments was not noted in any instance. It is well to remember that, at a period of twenty months or more following injury, definite determination of complete continuity of cruciate ligament structures is difficult. One patient had a small, well-encapsulated xanthoma attached to the anterior cruciate ligament and this was removed, including the synovium at the base of the pedicle. Six months later no recurrence had developed.

The operative procedure routinely has consisted of excision of the medial meniscus and transplantation of the intact semitendinosus as described above. Hospitalization varied from six to sixteen days, and all patients were weight-bearing on crutches within that time. In two patients pillow splints were applied postoperatively, but all of the others had only simple dressings with elastic bandages. Two patients had considerable hematoma and swelling, but in neither instance was aspiration done and both subsided satisfactorily. No infections, deaths, or other complications occurred.

Recovery of motion postoperatively is slower than after a simple excision of the medial meniscus but is steadily progressive. At one month postoperatively, a good average of recovery would show active extension at 180 degrees and flexion at 150 degrees. At three months, flexion would have increased to 100 degrees, at five months to 60 degrees. Of the four patients who were operated upon over a year ago, three have normal motion as compared with the opposite extremity, and one has a 20-degree limitation of flexion only.

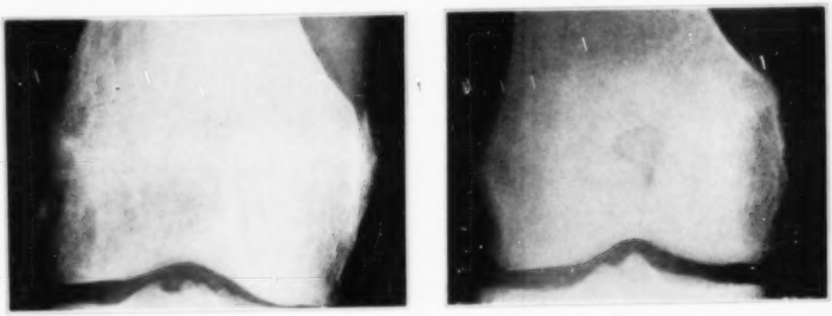

Fig. 3 Fig. 4

Postoperative roentgenographic findings. Many months after operation there is a mild mound of ossification in the region of the medial epicondyle of the femur in one patient; in another there is slight calcification of soft tissues at the same location.

Of the four patients operated upon over a year ago, two are completely stable both in flexion and extension, and two have a slight spring of the medial collateral ligament structure in flexion. All four are back at regular work, which includes that of chief engineer at a hotel, fireman on a railroad, bus driver, and policeman. The patient who is back on regular police duty was a motor-cycle officer and we have not permitted him to resume the kicking required to start a cycle.

Two of the six patients whose operations were less than a year ago may be said to have taken the bit in their teeth. One of them began skiing three months after operation and the other one went on his honeymoon two months after operation. Neither has any complaints.

A preoperative roentgenographic study reveals negative findings. Postoperatively (Figs. 3 and 4), a moderate mounding ossification may be present at the point of transplantation of the semitendinosus beneath the medial epicondyle; diffuse calcification and ossification may be seen in the soft tissues; or a loose remnant of the raised cortex may appear.

COMMENT

The above method of repairing or replacing the lacerated medial collateral ligament of the knee seems both logically and by experience to be as satisfactory as any method we have knowledge of at present. There are certain advantages which give it favor over fascial repairs. It well may be that without our knowledge others have preceded us with reports of such operative repair, published or unpublished. If not, we may have added a step to the control of such lesions. If so, we may have spread the knowledge more widely that such repair is possible and useful.

CONCLUSIONS

1. Transplantation of the intact semitendinosus for repair or replacement of the medial collateral ligament is a sound procedure on an anatomical, mechanical, and clinical basis.

2. When injury to a knee has been severe enough to lacerate or avulse a medial collateral ligament, other co-existing pathological changes are to be expected and may need definitive care at time of surgery.

3. Any type of late repair of such a badly damaged structure may be expected to leave certain residual abnormalities. Each procedure submitted will have to be judged by the amount of relief provided to the greatest percentage of patients by the average sur-

geon later using such procedure. Therefore, in this, as in any new or variant procedure, final results are not now fully determinable.

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THE MILCH FASCIODESIS FOR THE RECONSTRUCTION OF THE TIBIAL COLLATERAL LIGAMENT

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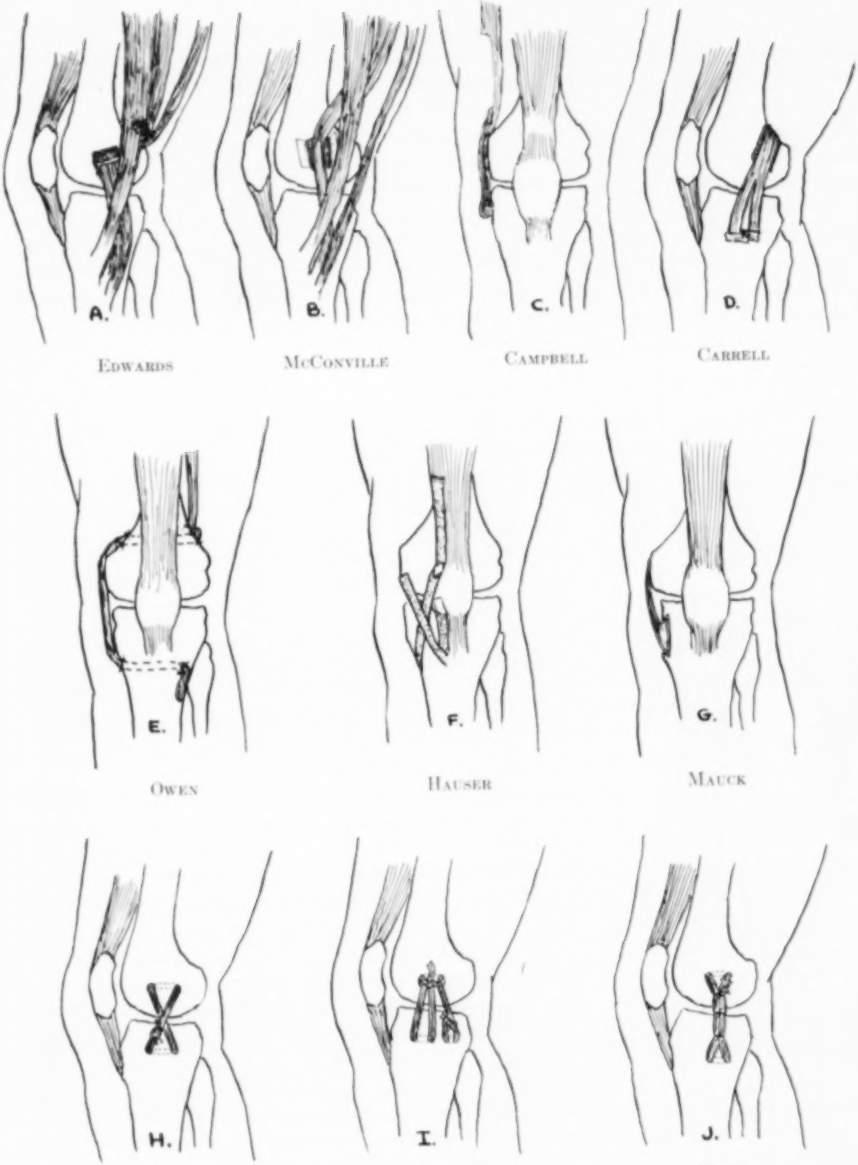
Hey Groves [14], in 1917, described an original technique for the repair of torn anterior cruciate ligaments, utilizing a fascial strip. Improvement in the results of this procedure, which were reported by Smith in 1918, who added to the technique repair of the tibial collateral ligament, led Hey Groves [15] to modify the technique in such a manner that the reconstruction of the anterior cruciate ligament was combined with the reconstruction of the tibial collateral ligament.

Milch [22, 23] went further when he treated combined ruptures of these ligaments without regard to the injury of the cruciate ligaments. He repeatedly demonstrated at operation the fact that the excision of the isolated, torn cruciate ligament left little if any disability and that the repair of the tibial collateral ligament alone, when both were injured, resulted in the restoration of anteroposterior and lateral stability without impairment of function of the knee joint. From these experiences, which have been confirmed by anatomical studies and which have been observed clinically by others, the conclusion has been reached that the tibial collateral ligament is of the utmost importance in the stability of the knee joint.

It has often been demonstrated that wisely planned conservative therapy usually suffices for most of the acute ruptures of the tibial collateral ligament of the knee joint provided that the lateral mobility does not exceed more than 5 degrees [1, 10]. When the tear is so extensive that conservative treatment is precluded, operative repair must be undertaken. When appropriate conservative treatment has failed, exploration and repair are mandatory. Many different methods have been devised for the surgical repair and reconstruction of this ligament.

The operations in use are based upon the following procedures: (1) reefing of the capsule with fascial reinforcement [3, 4], (2) tendon transplants [5, 13, 16, 17, 18, 20, 21] (Fig. 1, *A*, *B*, and *F*), (3) transplantation of the tibial collateral ligament [19] (Fig. 1, *G*), (4) reflections of fascia lata [9, 11, 24, 27] (Fig. 1, *C*, *D*, and *E*), and (5) free fascial grafts [6, 12, 23] (Fig. 1, *H*, *I*, and *J*).

Many of these procedures are unnecessarily extensive, and they usually sacrifice the fascial and tendinous support of the neighboring structures. In addition, in most of the procedures osseous fixation, anatomical reconstruction, and the restoration of physiological tension is lacking. Some create inadequate duplicates of the normal ligament, while others



Edwards McConville Campbell Carrell

Owen Hauser Mauck

Cotton Bosworth Milch

Fig. 1

Drawings illustrate the procedures used in the reconstruction of the tibial collateral ligament.

require an additional incision for the removal of a torn medial meniscus which is often associated with the ligamentous injury.

In his original communication on the subject, Milch [22] called attention to the particular anatomy of the tibial collateral ligament, and Brantigan and Voshell [6, 7], in their comprehensive articles, have corroborated and amplified these observations. From the point of view of kinesiology, the important anatomical fact is that the anterior or the thickened portion of the tibial collateral ligament remains under constant tension in all positions of the knee joint,—especially in flexion, when the posterior portion of the ligament becomes relaxed. Milch, therefore, reasoned that the anterior portion of the ligament must be anatomically replaced in order to provide resumption of the physiological function of the ligament throughout the range of motion and that the operation must be designed to meet all contingencies while restoring the stabilizing function of the ligament as a whole. It has been shown [23, 25] that ruptures may occur at either end of the ligament and that, because of subsequent fibrosis, they are indistinguishable at operation. The Milch procedure consists in the repairing of tears of the tibial collateral ligament regardless of the site of their occurrence. In addition, while the operation is performed as an extra-articular procedure, the approach used permits easy exploratory arthrotomy.

OPERATION

The Milch fasciodesis [23] is begun with a curved L-shaped incision approximately six inches long on the anteromedial aspect of the knee joint (Fig. 2). It extends from a point just below the level of the adductor tubercle to a point about one inch below the level of the articular surface of the medial condyle and thence is carried forward towards, but just short of, the edge of the ligamentum patellae, roughly paralleling the infrapatellar branch of the saphenous nerve which is thereby avoided. When the skin flaps have been reflected and properly draped, the deep fascia and the quadriceps expansion are incised in the same line and are reflected back as a separate layer. The tibial collateral ligament is then seen exposed in the posterior part of the incision, and in the inferior portion of the wound the anterior half of the medial meniscus is seen running from the anterior edge of the tibial collateral ligament forward to the ligamentum patellae. It is in this area that the medial compartment of the joint is opened and explored. Torn menisci or cruciate ligaments, or both, are excised, and the synovial membrane is closed tightly. The upper and lower attachments of the anterior portion of the tibial collateral ligament are then clearly exposed and two drill holes are made at each end of the ligament by use of a three-eighths-of-an-inch hand drill. The two upper drill holes are connected by a channel passing transversely beneath the femoral attachment of the ligament and the two lower drill holes are connected by a bone tunnel beneath the tibial attachment (Fig. 3). By means of a fascial stripper, a piece of fascia approximately ten inches long and one-half of an inch wide is subcutaneously cut from the fascia lata on the lateral side of the thigh. This fascial graft is passed in and out through the upper two drill holes, and then down, paralleling the tibial collateral ligament, through the two lower drill holes, and then up again to its origin. At this point, while the leg is held in hyperadduction, the remnants of the injured collateral ligament are repaired with several interrupted chromic catgut sutures. This maintains the leg in adduction on the femur and, at the same time, eliminates tension on the graft during the period immediately following operation. The fascial graft is now sutured to the periosteum both as it enters and as it emerges from the femoral drill holes. The graft is pulled taut, and it is again sutured as it enters and emerges from the tibial holes; the ascending limb of the graft is pulled taut and sutured to its free end. Thus the tibial collateral ligament is outlined on four sides by a quadrilateral graft.

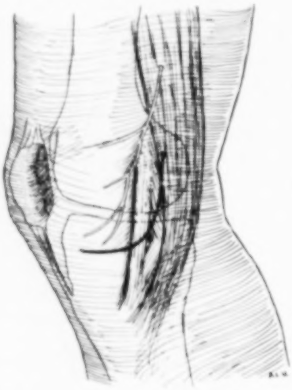


FIG. 2

Fig. 2: The relationship of the skin incision to the underlying structures is shown.

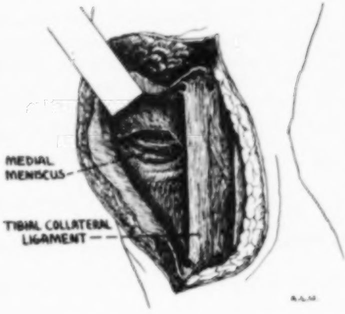


Fig. 3

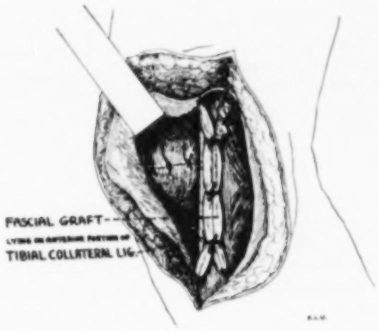


Fig. 4

Fig. 3: The approach to the medial meniscus and the relationship of the drill holes to the anterior portion of the tibial collateral ligament are shown.

Fig. 4: Note the fascial graft lying on the anterior portion of the tibial collateral ligament. The limbs have been pulled taut and have been sutured to each other.

The ascending and descending limbs of the graft are exposed, while the transverse limbs are buried in the bone canals. The two vertical limbs are sutured to each other directly over the anterior part of the collateral ligament so as to increase still further the tension under which they are placed (Fig. 4). The fascia and the skin are then closed in layers with interrupted chromic catgut and silk sutures. A plaster-of-Paris bandage is applied, with the leg in adduction, and worn for three weeks, at which time it is removed and a hinged plaster cast which permits early motion is applied for another three weeks. This is followed by active weight-bearing with the patient wearing a knee-cage brace and inner wedges on his shoes to prevent excessive tension on the new ligament. Active exercises in the swimming pool and resistance exercises are practiced intensively.

REPORT OF CASES

Case 1. A. B., a seventeen-year-old male student, was admitted on October 11, 1949, with a complaint of pain and recurrent swelling of the right knee. Three months prior to admission, while wrestling, his adversary fell against the patient's right knee, forcibly abducting it. Pain and swelling were marked within twenty-four hours. On several occasions fluid was removed from the knee joint in the Out-Patient Department. He continued, however, to complain of pain, swelling, "sensation of giving way of the joint", and "clicking" at the medial aspect of the knee joint. There was no history of locking. Examination revealed a moderate swelling of the right knee with slight atrophy of the quadriceps. A patellar click was elicited and there was moderate tenderness on the medial side of the joint anterior to the tibial collateral ligament. Extension was possible to 185 degrees and flexion to 25 degrees. With the knee in extension, there was instability on the medial side of the joint as demonstrated by increased motion. Anteroposterior ligamentous instability was revealed by a positive "drawer" sign, indicating injuries to the cruciate and the tibial collateral ligaments. Abduction and adduction roentgenograms of both knee joints showed a considerable increase of motion in the right knee. At operation on October 17, 1949, the femoral attachment of the tibial collateral ligament was found to be completely frayed out, detached, and flattened. Both cruciate ligaments were torn and were therefore resected. The medial meniscus which was detached was also removed. After reconstruction of the tibial collateral ligament, with the wound still open, it was demonstrated that the anteroposterior and lateral instability were completely eliminated. After the wound was closed, a plaster-of-Paris cylinder was applied with the limb in extension and adduction. When seen in the Out-Patient Department ten months after the operation, there was no loss in stability and the patient had an almost complete range of flexion and extension.

Case 2. D. M., an attendant, twenty-five years old, was admitted on April 20, 1950, with a history of ten years' duration of recurrent pain and locking of the left knee joint. At the age of fifteen he had jumped from a moving vehicle and had suffered a fractured right tibia and "sprain" of the left knee. Since the accident he had had attacks of "locking" or "giving way" of the joint with pain and swelling. The pain was localized to the anteromedial portion of the joint. Examination of the left knee joint revealed a slight swelling and moderate tenderness on the medial side. Extension was possible to 180 degrees and flexion to 30 degrees. Considerable lateral instability was demonstrated on the medial side of the knee joint and a positive "drawer" sign was obtained. At operation on May 1, 1950, the upper end of the tibial collateral ligament was found to be thin, frayed out, and of a different texture than the remainder of the ligament. On opening the joint, the femoral attachment of the anterior cruciate ligament was seen to be torn away and frayed out. The ligament was excised. The medial meniscus which was detached was removed. Immediately after the fascial repair of the medial collateral ligament, the anteroposterior and lateral mobility completely disappeared. Three and one-half months after operation the knee joint was quite stable; and flexion and extension were complete.

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ARTHRODESIS OF THE ELBOW JOINT

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As has been pointed out by several authors [2,6,7], surgical arthrodesis of the elbow joint is frequently unsuccessful. One of the chief difficulties in producing a successful arthrodesis is the presence of only a short segment of bone distally—the olecranon—to which a bone graft can be fixed. Fusing operations on this joint are carried out posteriorly or from the side because of anatomical considerations and the elbow is ordinarily fused in some degree of flexion.

Several methods for arthrodesis of the elbow joint have been proposed and described [1,2,3,4,6,7], each of which has certain advantages. It is the purpose of this article to describe still another method which provides maximum contact of the bone graft and distal bone segment with firm fixation of the graft. The method utilizes an approach similar to that described by MacAusland, including transverse section of the olecranon process and retraction proximally of the proximal olecranon fragment with attached triceps tendon, exposing the elbow joint. When completed, an iliac-bone graft lies in contact with the posterior aspects of the humerus and elbow joint and between the two olecranon segments (Fig. 1).

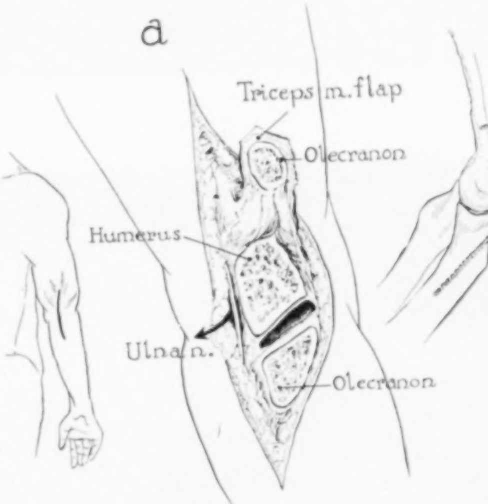

FIG. 1

a. Operative approach. *b.* Position of bone graft.

The operative technique was devised with a particular patient in mind. This patient had an old healed gunshot wound of the elbow with marked soft-tissue scarring and muscle defects and marked distortion of the lower portion of the humerus. Because of these defects, an operation to produce arthrodesis was performed, according to Steindler's technique, rather than an arthroplasty. This operation failed and, because other techniques seemed not applicable to this patient, the method here reported was used. Because of the relative simplicity in applying the technique in this instance and because of the prompt, solid, bony fusion which followed, it is felt that a wider application of this technique is justified.

OPERATIVE TECHNIQUE

A straight, longitudinal incision is made posteriorly over the elbow, running from a point about four inches proximal to the olecranon tip to one three inches distal to it. Through this incision the triceps tendon, proximal end of the ulna, and ulnar nerve are exposed. The ulnar nerve is carefully retracted and a transverse osteotomy of the olecranon process is carried out. This osteotomy is so planned that, when the elbow is held

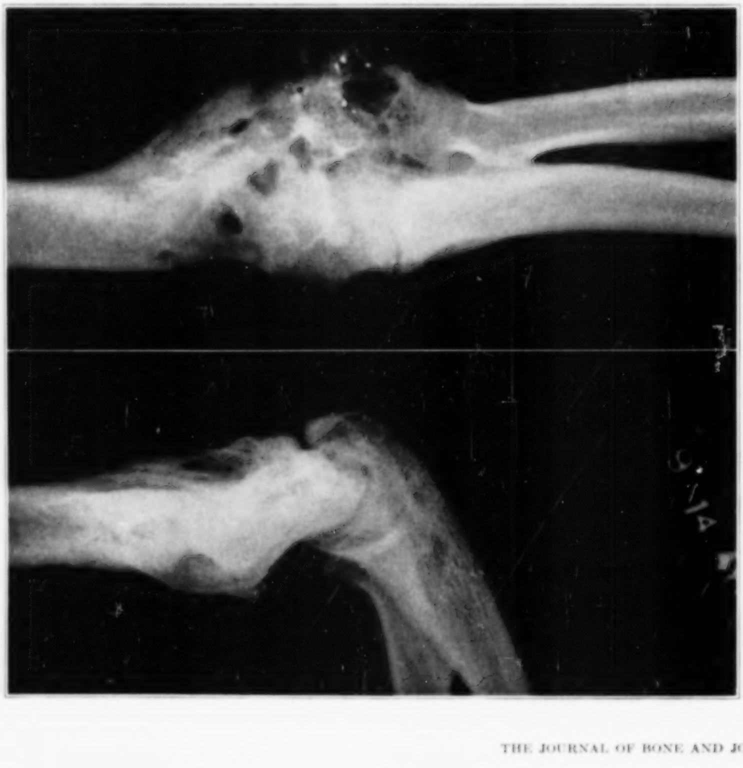

FIG. 2

E. A. L. Elbow before second operation.

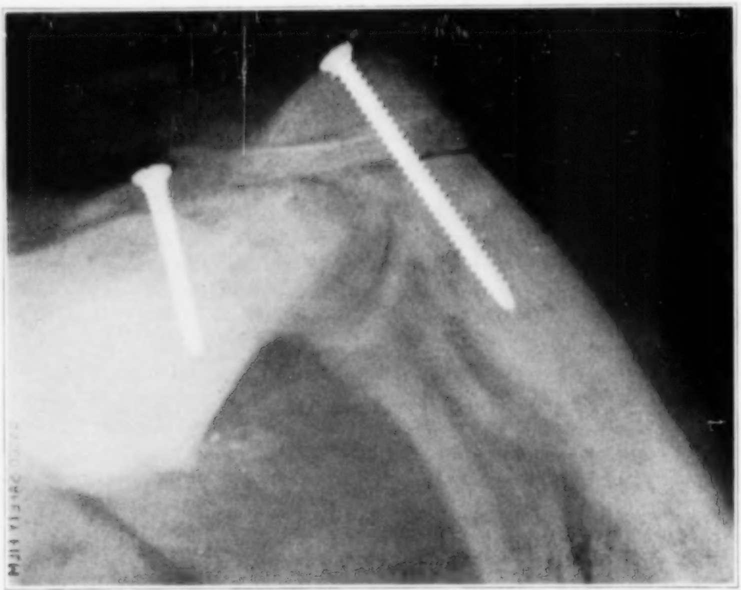

FIG. 3

Roentgenogram one week postoperatively.

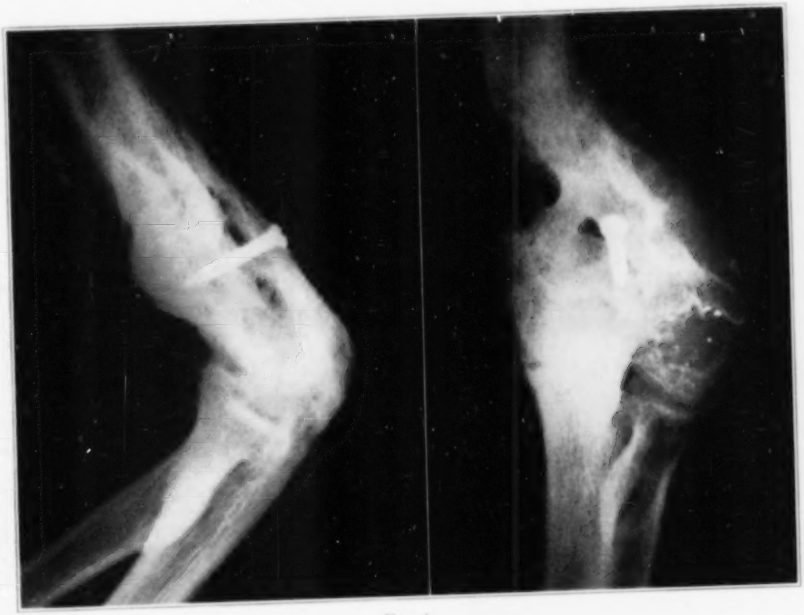

FIG. 4

Final roentgenogram, two years and eight months after second arthrodesing operation.

in the position elected for fusion, the plane of osteotomy of the olecranon will be parallel to and at the same level as the posterior aspect of the humerus (Fig. 1, *b*). After the proximal olecranon fragment has been freed, the triceps tendon is split medially and laterally from the two edges of the olecranon osteotomy, some three inches in a proximal direction. The tendon is left attached to the proximal olecranon fragment. The flap of soft tissue and bone thus formed is dissected from the underlying humerus and retracted proximally, exposing the posterior aspect of the elbow joint (Fig. 1, *a*). The posterior half of the elbow joint is cleaned out, soft tissue and articular cartilage being removed. Cleaning out of the anterior aspect of the joint is not necessary unless mobilization of the elbow to change its position requires it. By an osteotome the lower three inches of the posterior aspect of the humerus is planed down to a flat surface of bleeding bone. Further trimming of the distal humerus is planed down to a flat surface of bleeding bone. Further trimming of the distal olecranon segment will probably be necessary to match the planes of humerus and olecranon.

Following this, a half-thickness, iliac-bone graft taken from the anterior aspect of the anterior third of the iliac crest, some one-fourth to three-eighths inch thick, one inch wide, and three and a half inches long, is fitted into place, cancellous side anterior. It should cover the distal osteotomized surface of the olecranon, the elbow joint, and the lower portion of the humerus. It should be trimmed distally to match the outline of the olecranon. After the elbow joint space has been packed with cancellous chips, the graft is finally adjusted and held to the humerus by one Vitallium screw. The elbow is then placed in the proper position and the triceps-olecranon flap is replaced over the graft and fixed by one Vitallium screw passing through the proximal olecranon segment, the iliac graft, and the distal olecranon segment (Fig. 1). Before this screw is inserted into its drill hole, the entrance of the drill hole should be reamed so that the head of the screw will not protrude, because of its superficial position. After closure of the wound, a plaster shoulder spica cast is applied, including the entire arm and the iliac crest. This is maintained until there is roentgenographic evidence of bony union.

CASE E. A. L.: A carpenter, twenty-two years old, entered the White River Junction Veterans Hospital on February 20, 1948, complaining of pain and limitation of motion of the right elbow, due to a healed gunshot wound incurred while on army duty on November 4, 1944. On examination, the wounds were found to be well healed, though massive scars and muscle defects were present medially and laterally over the elbow joint. A jog of painful flexion was present. Rotation of the forearm was only moderately diminished. The elbow was in a position of about 70 degrees of flexion. Roentgenograms showed a destroyed elbow joint with fractures of the lower portion of the humerus, healed with considerable anatomical distortion. Because of the damage to soft tissue and bone and because in his work strength and absence of pain were more important to him than motion, an arthrodesis was chosen as treatment. On February 12, 1948, an operation, aimed to produce arthrodesis, was done according to Steindler's technique, using an iliac-bone graft. A position of 60 degrees of flexion had been selected as optimum for the patient's needs. A plaster shoulder spica cast was applied, including the entire right upper extremity to the base of the fingers and including the iliac crests. Postoperative roentgenograms showed good position of the graft and of the elbow segments. The patient was discharged from the hospital on February 27, 1948, with the wound well healed.

The cast was maintained in place for four months, at which time it was evident, both clinically and by roentgenogram, that non-union was present. A trial of function was carried out, but pain in the elbow soon recurred.

On October 4, 1948, the patient was readmitted to the hospital and arthrodesis was again attempted on October 7, 1948, by means of the technique described above. The convalescence was uneventful. Four months postoperatively the plaster spica cast was removed, at which time solid union of the arthrodesis was obvious clinically and by roentgenogram. Restoration of function progressed well and in a few weeks the patient was able to work, using the right arm.

A little over a year postoperatively, tenderness and later redness and sinus formation over the olecranon occurred. On February 16, 1950, the patient was readmitted to the hospital. It was felt that the symptoms were due to inflammatory reaction around the head of the screw in the olecranon, which had obviously not been countersunk deeply enough. The sinus present over the tip of the olecranon was excised and the underlying screw was removed. This operation was performed on February 21, 1950; the wound was tightly sutured. The wound had healed *per primum* at the time of discharge from the hospital two weeks later.

The patient was last examined on June 15, 1951, two years and eight months after the second arthrodesing operation (Fig. 4). At that time the patient had some pain in his shoulder, consistent with non-disabling strain. There had been no elbow pain or tenderness. His arm was somewhat awkward, but he was able to work in a factory, using both arms. Examination showed that his elbow was fused clinically. There was a range in rotation of from 50 degrees of pronation to 85 degrees of supination. No tenderness or redness was present. His scars and wounds were well healed. There had been no further redness or drainage from the operative site.

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ARTHROGRYPOSIS MULTIPLEX CONGENITA IN TWINS

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Arthrogryposis multiplex congenita, or amyoplasia congenita, is a rare and baffling disease characterized by symmetrical limitation of motion of the joints of the extremities, present at birth and non-progressive in character. The deformity is said to be secondary to an aplasia or dystrophy of the musculature of the extremities, as the joints are normally formed and the stiffness appears to be due to fibrous replacement of muscle. The lack of foetal joint motion is usually confirmed by the mother.

As this is a prenatal phenomenon and as the disease is quite rare, the opportunity for study has been limited. Few cases have been reported in the literature, and the theories as to etiology have been many. For a great number of years, these deformities were considered to be groups of unassociated congenital anomalies. Rocher[6], who collected the first series of cases, believed that compression of the limbs *in utero* was the cause. Stern, in 1923, reported four cases and believed that the basic pathological factor was the thickening of periarticular structures, possibly secondary to intra-uterine joint inflammation. Roberts later reported a strikingly similar disease in sheep which was proved to be carried by a recessive gene, thus opening the discussion as to whether the condition was hereditary in man. Middleton, in 1934, performed autopsies on affected sheep and on one infant shortly after birth and concluded that "the deformity results from a fatty degeneration of the limb-muscles occurring during intra-uterine life". Sheldon, in 1932, stated that the disease was an aplasia rather than a dystrophy, and Badgley carried this further with his theory of embryonic arrest; he noted that the characteristic deformities of the disease were indicative of an arrest of muscle development and consequent failure of rotation of the limbs which normally occurs during the third month of foetal life.

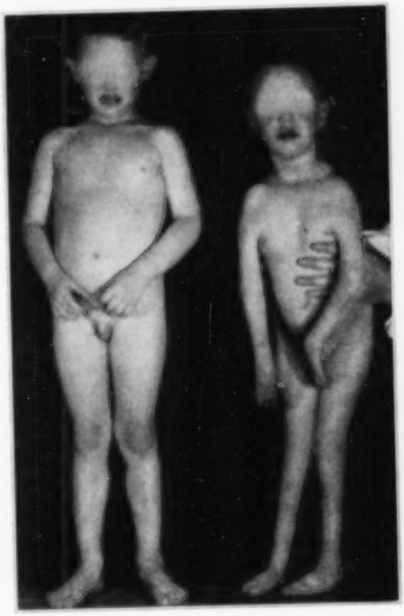

Fig. 1

Right: Case 1, D. W. Severe involvement of upper and lower extremities.
Left: Case 2, R. W. Normal twin.

We have been able to study two sets of identical twins in which one child of each set had classical arthrogryposis, while the other twin was entirely normal. We could find no similar cases reported in the literature.

Gruenwald and others have stated the difficulty of drawing conclusions on the origin of malformations from a study of single cases or small series, but the authors believe that the cases to be presented offer a unique opportunity for study of this disease from an etiological and a genetic standpoint.

CASE REPORTS

CASE 1. CHS5746, D. W., male, eight months old, was admitted to the Children's Hospital School, Baltimore, Maryland, for the first time on August 14, 1945, with presenting symptoms of stiffness and deformity of all extremities, present since birth. The family were free of any congenital abnormalities. The patient was one of twins, born one month before term after a normal pregnancy. The twin brother (Case 2, R. W.) was a vertex presentation, followed a few minutes later by the patient (D. W.) in the breech position. No record was made concerning the placenta. The patient weighed slightly less than four pounds, his twin slightly more than six pounds. D. W. was immediately noted to have stiffness of all extremities and clubbed hands and feet, with marked lack of movement of the limbs. There were no postnatal problems other than the severe deformity, which was not progressive but was very resistant to manipulation at home.

Physical examination on admission showed a relatively well-nourished infant with a rather expressionless and grimacing face. There was wasting and marked internal rotation of the shoulders, with limitation of motion in all directions. The elbows were stiff in extension, the wrists flexed to 90 degrees. The fingers were moderately stiff in flexion. There was little active motion except in the thoracoscapular muscles and in the finger flexors. The trunk muscles were normal. The hips were in 45 degrees of external rotation, but on each side the range of active motion was fairly good. The knees were in full extension with only 30 degrees of flexion possible. There was marked equinovarus deformity of the feet, with the toes fixed in flexion.

On the first admission, the patient remained only four days, but he was returned October 22, 1948 at the age of four with essentially the same physical findings; he had had no medical problems other than those imposed by his deformity. He was able to stand if supported, eat well, and talk with a minimal speech defect that seemed more mechanical than intellectual in origin. An intensive course of physical therapy, wedged casts, and manipulations was undertaken. An arthroplasty of the left elbow produced no additional active motion, but the elbow was carried in a position of 40 degrees of flexion. Marked sparsity of muscle tissue was noted at operation, but a biopsy showed the muscle present to be entirely normal.

The child was discharged on October 14, 1949. The deformities of the feet and hands were improved, and he was able to get about well in a small walker and to feed himself with a mechanical feeding device. Since his discharge he has been followed in the Out-Patient Department and has shown further progress in becoming independent.

CASE 2. R. W., male, twin of Case 1. This child is entirely normal in all respects.

CASE 3. CHS6850, J. S., female, was admitted to the Children's Hospital School March 7, 1949, at the age of fourteen months, with presenting symptoms of stiffness of both arms, present since birth. The family history was negative for congenital abnormalities. Two older siblings were normal. The patient was born after a normal full-term pregnancy as a breech presentation, her twin (Case 4, J. S.) being vertex. A single placenta was noted, and the mother was told that the twins were identical. Marked stiffness and impairment of muscle activity in the upper extremities was immediately noted in this patient while the twin was perfectly normal. The postnatal development of both children was uneventful, both gaining weight well.

The patient had been treated from a few weeks of age with casts and exercises for the hands, and showed some improvement in their use. At ten months she was placed in a spica cast and the shoulders were gradually wedged into a position of abduction. This produced considerable improvement in the use of the arms for some time.

On admission, the physical examination revealed a healthy, alert, white female child of fourteen months with a normal trunk and lower extremities. Her head was normal except for a somewhat wooden smile. Her shoulders were small and assumed a position of internal rotation. The elbows were in extension with a range of 10 degrees of active and 30 degrees of passive motion. The wrists were in a position of flexion to 45 degrees, but the fingers were relatively mobile and the coordination of movements was good.

Treatment was by a bilateral shoulder spica with progressive wedging of the shoulder and elbows. Intensive physical therapy was instituted after the patient had been in the cast for three months; the correction was maintained by an adjustable double-abduction arm brace. Efforts to orient the child toward the use of her upper extremities rather than of the feet, with which she had become quite dexterous, were likewise gratifying.

She was discharged December 1, 1949 and has been followed as an out-patient. She wears her brace only at night and now uses her arms actively in playing; she is able to keep up with her sister in most of their activities.

CASE 4. L. S., female, twin of Case 3. This child is entirely normal in all respects.

DISCUSSION

It was agreed by all observers that both affected children showed clinical deformities which were compatible with arthrogryposis multiplex congenita and no other disease.

It was apparent to the authors that, if these sets of twins could be proved to be iden-

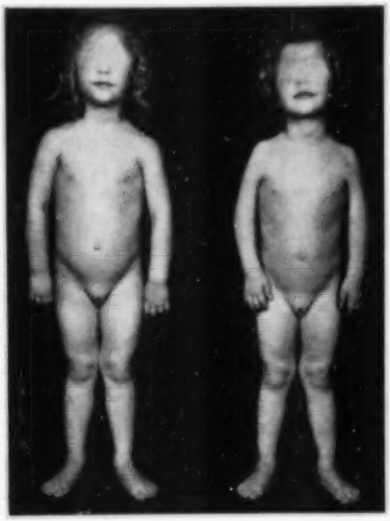

FIG. 2-A

February 21, 1951.
Right: Case 3, J. S. Involvement of upper extremities.
Left: Case 4, L. S. Normal twin.

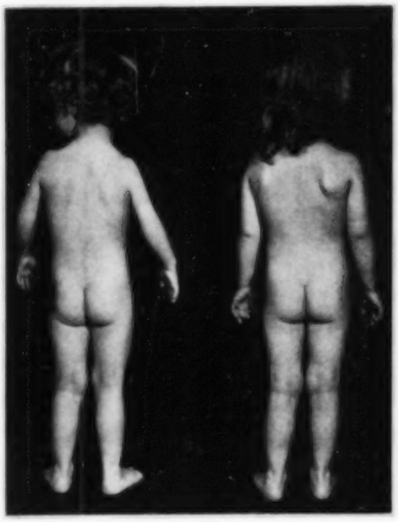

FIG. 2-B

February 21, 1951.
Right: Case 4, L. S. Normal twin.
Left: Case 3, J. S. Involvement of upper extremities.

tical, certain conclusions as to the non-genetic nature of the disease could be drawn, for if the twins were monozygotic, any dissimilarities would necessarily be unrelated to the chromosomes which contributed equally to their development.

To determine the fact that these sets of twins were monozygotic, criteria stated by Newman and others were investigated. These included: skin color and texture, hair color and texture, eye color and iris pattern, external ear configuration, dentition, hair patterns of the dorsal interphalangeal skin, fingerprints, and blood groups and sub-groups (Table I). Cross-transfers of skin grafts were not performed. In all these tests, the similarities were remarkable, and the degree of correlation of blood groups was considered conclusive. From this evidence it is clear that the twins are monozygotic and therefore one may conclude with certainty that the mechanism of the production of the abnormality in these cases was not within the chromosomes. It is theoretically possible that a mutational change of one or more of the chromosomes could have occurred some time after the original cleavage of the ovum. This is unlikely, since the only recognized variations which occur in monozygotic twins are mirror-imaging, distorted development of one side of the body, or a grossly malformed foetus, the latter suggesting either late cleavage of the ovum or impaired intra-uterine nutrition.

TABLE I

BLOOD GROUPING DATA

Case 1.	OM S+ Rh_1rh	Case 3.	OMN S− Rh_1Hr' +
Case 2.	OM S+ Rh_1rh	Case 4.	OMN S− Rh_1Hr' +

The authors were unable to find any recorded instances where a genetically controlled teratism had occurred in only one member of a set of proved monozygotic twins. This study included an investigation of the records of the Embryology Laboratory of the Carnegie Institute in Washington and a review of the literature.

It is recognized that many hereditary abnormalities may be imitated by non-genetic abnormalities if some process intervenes locally in the development of the embryo. An example would be rumplessness in chickens, which is an abnormality produced in indistinguishable form either by selective breeding of the flock or by chilling of the egg at the proper time in the post-fertilization period. Likewise, the defects of infants born of mothers who have had rubella are closely correlated with the stage of embryonic development of the child at the time the mother had the disease, and they may closely resemble recognized defects. In the children described, the appearance of one entirely normal child from the identical intra-uterine environment and genetic susceptibility would strongly conflict with a theory of maternal infection, impaired nutrition, toxicity, or other secondary injury.

One is therefore left with evidence that the disease is neither a chromosomal defect nor a mutation of a normally fertilized and divided ovum. This renders the etiological concept of the disease as an aplasia or lack of proper development of muscles hard to explain or defend. However, if one turns to the next most popular theory, that of an intra-uterine muscle dystrophy or regression of normally formed foetal musculature, one is again hard pressed to explain why only one child would be involved and the other completely normal. The literature fails to show that the disease is common in twins or in special intra-uterine states, such as impaired foetal circulation, crowding, oligoamnios, breech presentation, or hydramnios; so one can indict no specific uterine environmental factors on the basis of these two instances.

These two cases, in so far as they represent a rather rare and poorly understood disease, cast grave doubts on many of the current concepts as to the basic etiology of arthrogryposis multiplex congenita. The cases and discussion are offered in support of no theory and the authors can advance no definite conclusions as to the cause of the condition. It is suggested, however, that this study limits the field of possibilities. The occurrence of abnormalities in one twin offers food for thought and for further study of the occurrence of congenital anomalies in general.

SUMMARY

Two sets of twins are presented, in which one child in each set has arthrogryposis multiplex congenita and the other child in each set is entirely normal. These are sets of identical twins, as demonstrated by both clinical and serological data. The disease in these instances could not have been genetically produced, since there is no deformity in the monozygotic twin. Doubt is expressed whether maternal infection or intra-uterine environment could affect one child and not the other. No current concept of etiology adequately accounts for the manifestations of the disease.

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RESECTION OF VERTEBRAL BODIES AND BONE-GRAFTING FOR CHRONIC OSTEOMYELITIS OF THE SPINE

A Case Report

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In considering the problem presented by a case of seemingly incurable osteomyelitis of the spine, a study was made of the literature on the resection of vertebral bodies as well as that on bone-grafting for osteomyelitis, for it was apparent that radical measures would be required. Although the literature is not extensive, several of the pioneers in orthopaedic surgery have, during the past thirty years, carried out various surgical procedures on vertebral bodies.

In 1934, Ito, Tsuchiya, and Asami reported the results in ten cases of tuberculosis of the vertebral bodies treated by radical surgery. Mayer, in 1946, reported six cases in which surgery was done on the bodies of vertebrae. Treatment in the first of these cases consisted in the incision and drainage of acute osteomyelitis of the fifth lumbar vertebra, which had first been done in 1923. In the other cases presented in this study, surgery on the vertebrae was carried out in the course of treating tuberculosis and an aneurysmal bone cyst as well as in biopsies for carcinoma and multiple myeloma. Compere, von Lackum, Smith, and Wiles have done vertebral surgery in treating congenital scoliosis of the hemivertebrae.

In reviewing the literature on bone-grafting in cases in which infection was present, the work of Prigge and of Coleman and his associates suggested the use of cancellous iliac

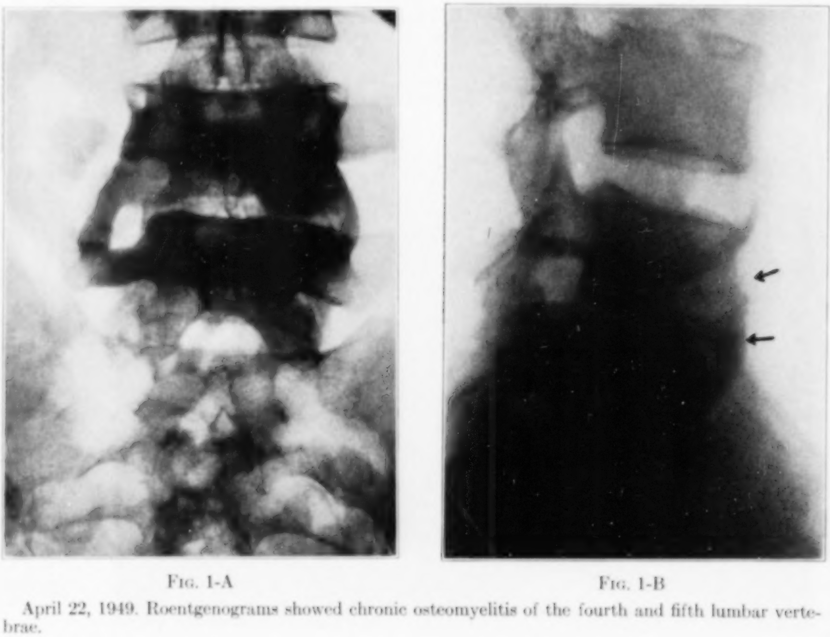

Fig. 1-A

Fig. 1-B

April 22, 1949. Roentgenograms showed chronic osteomyelitis of the fourth and fifth lumbar vertebrae.

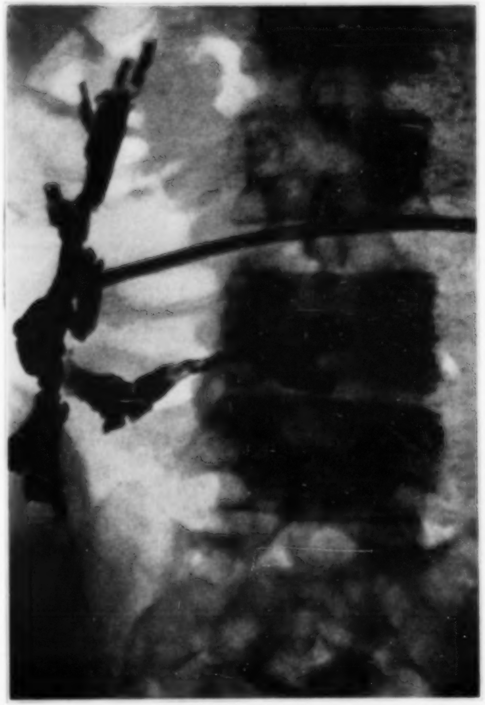

Fig. 2

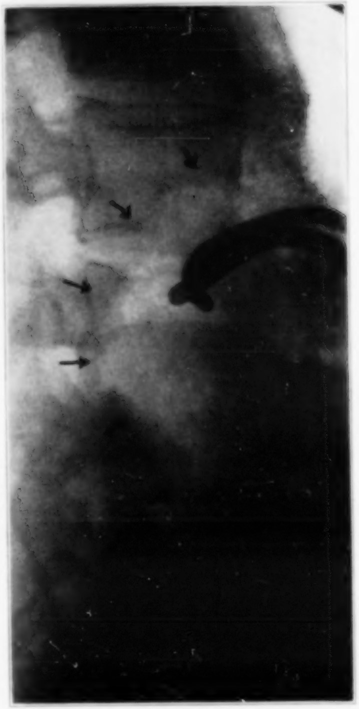

Fig. 3

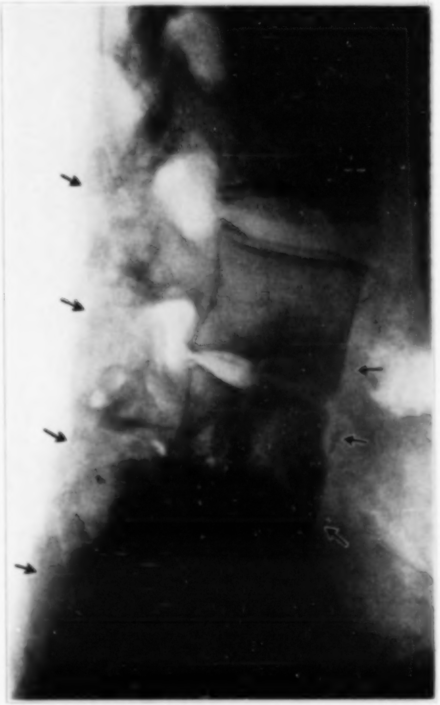

Fig. 4

Fig. 2: September 28, 1948. Roentgenogram made after the injection of radiopaque medium into sinus.

Fig. 3: April 29, 1949. Roentgenogram showed irrigating tubes in place following saucerization. Note the almost complete absence of the fourth and fifth lumbar vertebrae.

Fig. 4: June 1, 1950. Roentgenogram made following anterior and posterior bone-grafting.

bone grafts to fill the defects after saucerization of the infected bones. This method of bone-grafting has been used extensively with remarkable success.

Although these articles indicated that surgical procedures on the vertebral bodies were not uncommon and that cancellous bone-grafting for osteomyelitis was an accepted treatment, a careful search of the literature failed to reveal a case similar to the one here reported.

With the work of Prigge and Coleman and his associates in mind and following a suggestion by Herbert and LaChapelle advocating the sympathectomy approach to the vertebral bodies, the decision was made to undertake saucerization and cancellous bone-grafting. The patient had suffered from multiple deep abscesses over a period of three years, and he was slowly losing ground in a manner which is typical of patients suffering from osteomyelitis of the vertebral bodies.

CASE REPORT

E. F. E., a young adult male, was struck on January 29, 1946, by a .38-caliber bullet which was fired at close range. The bullet entered the left hip, went through the body of the fourth and fifth lumbar vertebrae, and lodged in the right lower abdomen, traversing the bowel in several places.

A colostomy and bowel suturing were performed by another surgeon; and, after a stormy course, the colostomy was closed.

Shortly after he was wounded, the patient began to have recurrent bouts of multiple abscess formation, and it was suspected that the abscesses originated from osteomyelitis of the fourth and fifth lumbar vertebrae (Figs. 1-A and 1-B).

Over a period of three years, this patient was treated with multiple transfusions, antibiotics, incision and drainage (sixteen times). Numerous bilateral, short hip spicas had been applied. During this time, the patient had lost twenty-seven pounds and he had become addicted to narcotics.

At this point, the patient realized that there was no hope for improvement through conservative treatment, and he stated his willingness to undergo any procedure which might improve his condition without regard to the risk involved.

To ascertain the precise location of the infection, a radiopaque medium was injected into one of the draining sinus. Roentgenograms (Fig. 2) were made which revealed that the sinus originated at the site of the osteomyelitis between the fourth and fifth lumbar vertebrae. Also, a Congo-red test was ordered to determine whether amyloidosis was present; the result of this test was negative. Plans were made, therefore, to saucerize the infected vertebrae.

On April 25, 1949, through a left anterior sympathectomy approach* a radical saucerization of the fourth and fifth lumbar vertebra

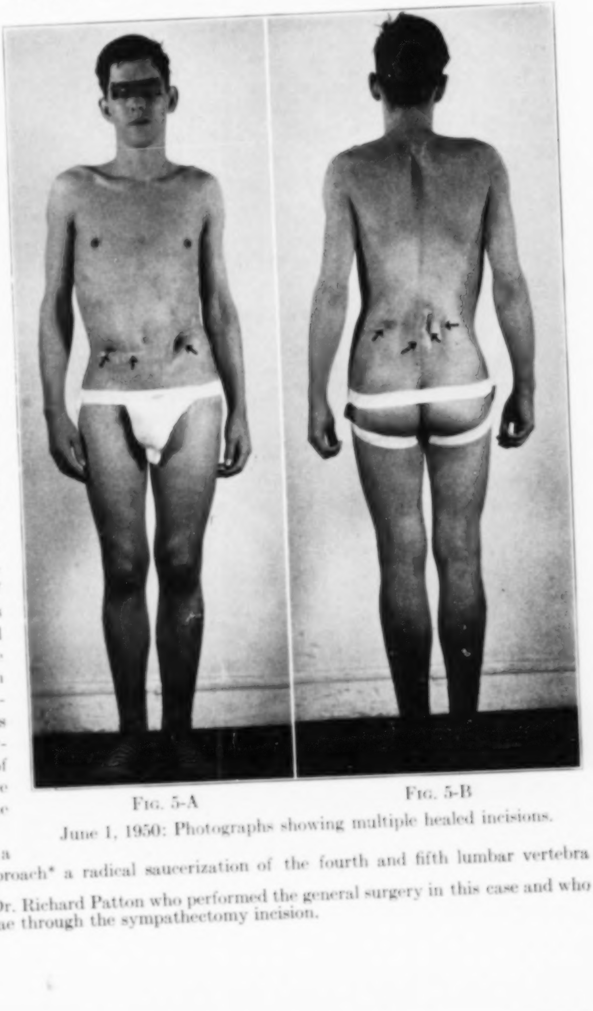

Fig. 5-A Fig. 5-B

June 1, 1950: Photographs showing multiple healed incisions.

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* The author is indebted to Dr. Richard Patton who performed the general surgery in this case and who helped him approach the vertebrae through the sympathectomy incision.

was accomplished. All but a thin posterior shell of the fifth lumbar vertebra and practically all of the fourth lumbar vertebra were removed (Fig. 3). The wound was packed open.

After the saucerization, the patient folded into a marked kyphosis, and it was necessary to apply a hyperextension, bilateral short hip spica with the patient on a Goldthwait frame.

For a period of six weeks after the operation, the packing was changed weekly through a hole in the cast. The patient was given a general anaesthetic, sodium pentothal, for this procedure. During the same period the open wound was irrigated four times daily with penicillin and streptomycin; parenteral injections of these drugs were also given.

On June 7, 1949, when the wound was completely clean, and after velvet-like granulation tissue had formed, a posterior modified Hibbs spine fusion was performed, using grafts of cancellous bone which were obtained from the wing of the right ilium. At the same time, the defects in the bodies of the vertebrae were filled with similar cancellous grafts. The anterior wound was packed loosely, since it could not be closed. A bilateral, short hip spica extending from the chest to the knees was then applied.

Postoperatively, the patient was again given large doses of parenteral antibiotics and sulfadiazine. He recovered from this operation, with the anterior wound filling in with granulating tissue and closing several months later. On October 6, 1949, a body cast was applied, and the patient was allowed to bear weight. Later, this cast was replaced by a chair-back brace which the patient wore for three months.

He was discharged from the hospital on February 1, 1950. As x-rays revealed that both the anterior and posterior spine fusions were solid, he was no longer required to wear the brace (Fig. 4).

After almost two years following the spine fusion the patient has regained his normal weight, has conquered his drug addiction, has experienced no more abscesses or sinus formation, and seems to be well in every respect (Figs. 5-A and 5-B).

DISCUSSION

With modern antibiotic therapy, multiple transfusions (thirty-five in this case), and with good surgical technique and facilities, it is possible to resect the bodies of vertebrae through a sympathectomy approach without too much difficulty, using, even with long-standing infection, bone grafts of infection-resistant, cancellous bone to fill the defects. It seems logical, therefore, to assume that the same procedure could be followed in the treatment of other pathological conditions,—such as the aneurysmal bone cyst reported in the paper by Mayer, other benign bone tumors, and possibly, in some resistant cases of tuberculosis.

The marked kyphosis following the radical saucerization was disconcerting, but it was successfully controlled by the hyperextension cast in which the facets were used as a fulcrum.

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STUDY OF INTERNAL FIXATION BY SCREWS OF OBLIQUE FRACTURES IN LONG BONES

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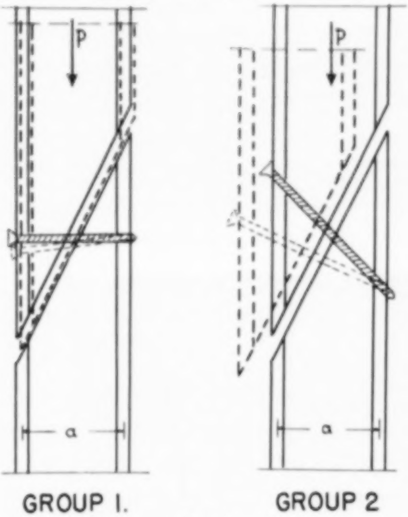
Determining the proper direction in which to drive screws for internal fixation of oblique fractures in long bones is a problem which surgeons frequently encounter. A study was undertaken to answer this question and to determine whether screws driven at certain angles to the cortex or to the fracture line might predispose toward non-union. Therefore, ten tibiae were removed from five reasonably similar cadavera, and in each a long oblique fracture near the mid-shaft area was produced with a band saw. Care was taken to have the band-saw cuts as smooth and as nearly similar as possible as regards length and the obliquity of the angle to the bone cortex. After production of the oblique fractures, three .164 Vitallium screws were driven through holes made with a nine-sixty-fourth-inch drill under different sets of conditions to be described.



GROUP I. GROUP 2

Fig. 1

Schematic presentation of the two methods of fixation in the same type of fracture.

P indicates the axial load and a the horizontal distance between the two points of fixation. The bending moment is $P\frac{a}{2}$.

The new position of the proximal fragment, after the resistance of the screws to bending has been overcome, is indicated by the dotted lines.

In four of the tibiae, Group 1, the screws were inserted perpendicularly to the shaft of the bone and equidistant to each other, and in each bone the end screws were equidistant from the corresponding ends of the fracture line (Fig. 2-A).

In the four specimens in Group 2 three screws were inserted in the same manner, but they were driven in at an angle of 45 degrees to the bone surface, which made them approximately perpendicular to the fracture line (Fig. 3-A).

In Group 3 a combination of the two methods of fixation was used; two screws were driven in perpendicular to the shaft and a third between them perpendicular to the fracture line (Fig. 4-A).

In order to study the differences between these methods of fixation in regard to their resistance to a vertical load, all specimens were subjected to test loading under the same conditions. The ends of the bones were removed by an electric saw for better application of the test loads. (A Riele mechanical testing machine was used.)

On the basis of the experiments carried out, the following observations were made:

1. The fixation screws were initially subjected to a bending moment caused by the axial load P, because of the fact that complete contact of the fracture surfaces is not possible in all cases of fixation.

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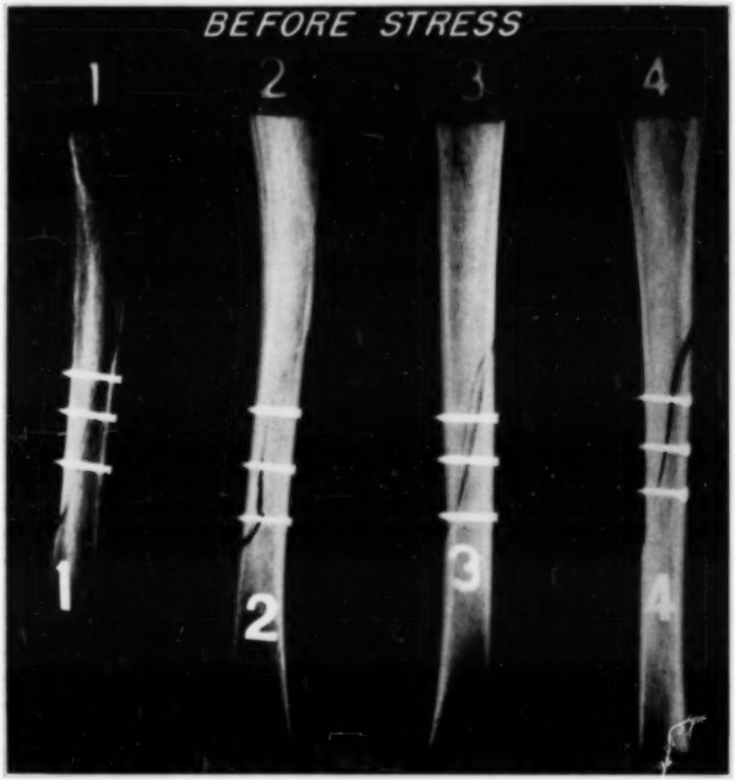
BEFORE STRESS
1
2
3
4

Fig. 2-A

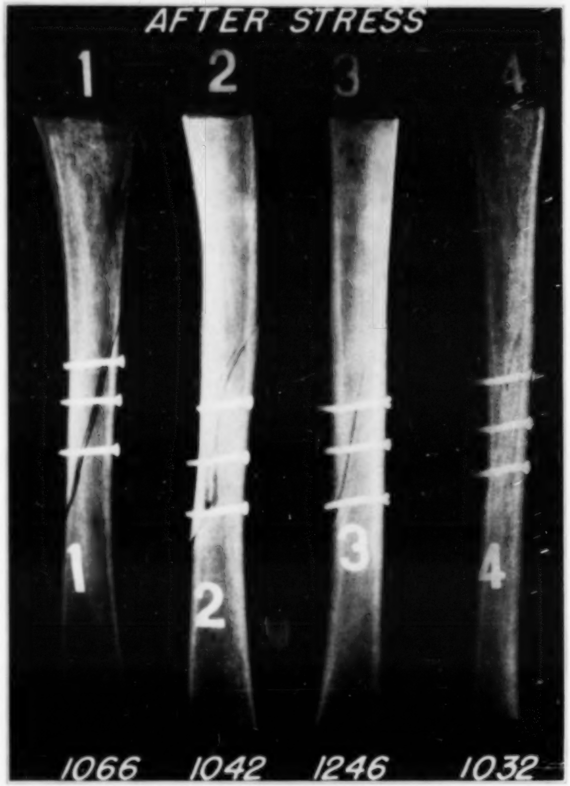
AFTER STRESS
1
2
3
4
1066
1042
1246
1032

Fig. 2-B

Specimens in Group 1 before and after application of test load. The numbers indicate the maximum amount of weight in pounds withstood by each specimen.

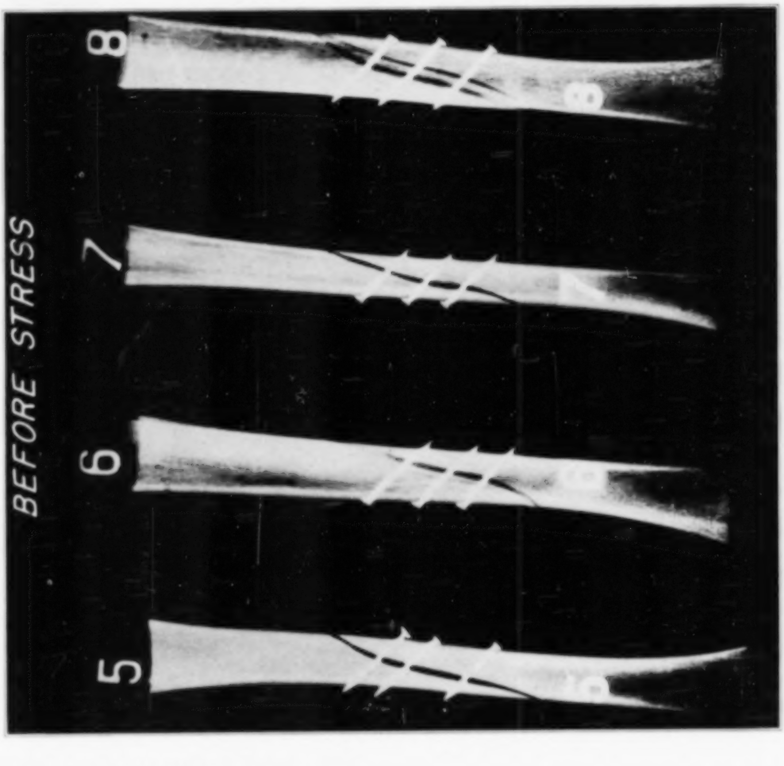
BEFORE STRESS
5
6
7
8

Fig. 3-A

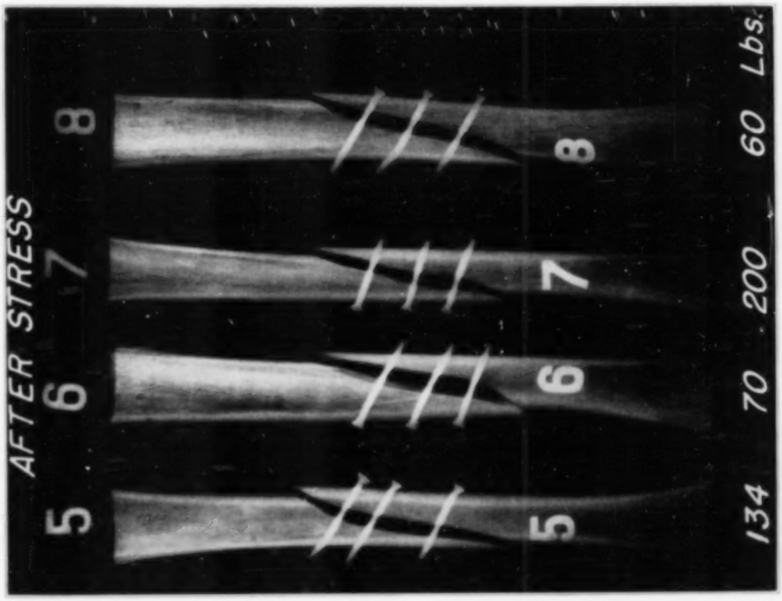
AFTER STRESS
5
6
7
8
134
70
200
60 Lbs.

Fig. 3-B

Specimens in Group 2 before and after test load.

TABLE I

RESISTANCE OF FIXATION TO LOAD

	No. of Specimen	Maximum Load Resisted (*In Pounds*)
Group 1	1	1066
	2	1042
	3	1246
	4	1032
Group 2	5	134
	6	70
	7	200
	8	60
Group 3	9	184
	10	526

2. Other conditions being equal as far as dimensions of the bones and the weight of the load are concerned, this initial bending moment is also the same and equals the

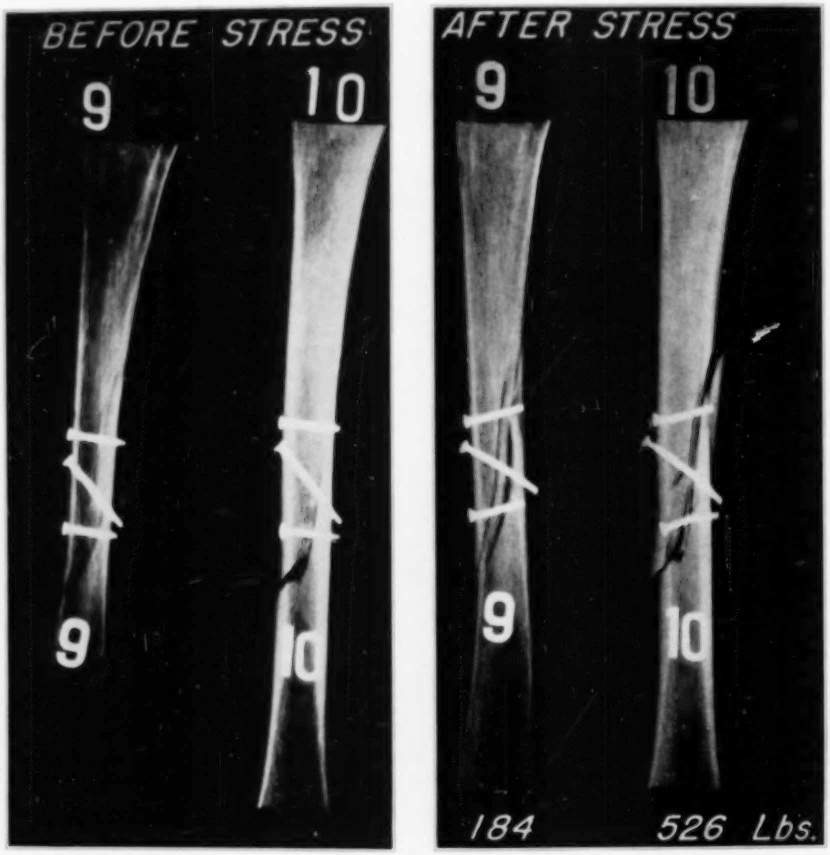

FIG. 4-A FIG. 4-B

Group 3. Both types of fixation were employed in these two specimens.

product of the axial load P and half the distance a between the two opposite sides of the bone at the points of fixation.

3. As soon as the resistance of the screws to the bending moment is overcome, the one fixed point tends to turn around its opposite on a radius equal to the length of the screw.

4. In Group 1, the rotation of the one fixed end about the other tends to decrease the distance a and to bring the surfaces of the fracture into closer contact (Fig. 1). The screw continues to resist as a member in tension, thereby increasing the contact pressures of the fracture surfaces and consequently the frictional resistance.

5. In Group 2, the rotation of the one fixed end about its opposite causes an increase in the distance a between the two points of fixation. As a result the bending moment increases, the resistance of the screw having been overcome. The two parts of fixation tend to move apart (Fig. 1).

6. Group 3 represents a combination of the characteristics of the two previous groups.

Table I shows the results of the test loading of the three groups of specimens. According to these results, the resistance of the fixation to the load in Group 1 was found to be somewhat more than nine times as great as the resistance of fixation in Group 2.

DISCUSSION

The experiment demonstrated that, when screws were inserted perpendicularly to the bone cortex, more efficient fixation resulted than when some or all of the screws were inserted at right angles to the fracture line.

Although we know that muscle spasm is never so high as to exceed the maximum of a thousand pounds withstood by the fragments fixed by the first method, there may easily be, even under normal conditions, a muscle force of the sixty to one hundred pounds sufficient to displace the fragments fixed by the second method.

It is important to note that even when the screws in the first group begin to bend there is a constantly increasing compression of the fracture surfaces, a factor of great value in the healing process of the fractures. In the second group the bones are constantly pulling apart, adding a factor which predisposes toward non-union.

SUMMARY

1. The most efficient internal screw fixation in oblique fractures is that in which the screws are inserted in a direction perpendicular to the bone cortex.

2. Test loading has shown that such application of screws results in an increase in the contact between the surfaces of the two fragments. The same effect should result from weight-bearing.

3. The amount of stress withstood by this type of fixation suggests that when the screws are properly inserted there is a sufficient margin of safety to permit earlier weight-bearing, especially if a circular plaster splint is used to take up the lateral stresses.

MYELOMA OF BONE

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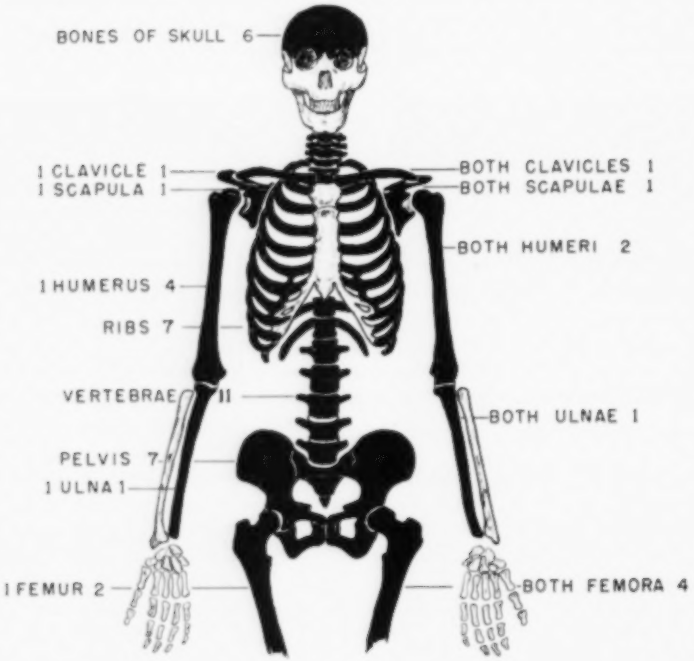
The purpose of this paper is to present briefly an analysis of the fourteen cases of microscopically proved myeloma of bone which have been seen at the Vanderbilt University Hospital, and to report the case of a patient who was still alive nine years after the diagnosis of myeloma had been made.

NUMBER OF PATIENTS WITH INVOLVEMENT OF INDICATED BONES


BONES OF SKULL 6
1 CLAVICLE 1
1 SCAPULA 1
BOTH CLAVICLES 1
BOTH SCAPULAE 1
BOTH HUMERI 2
1 HUMERUS 4
RIBS 7
VERTEBRAE 11
BOTH ULNAE 1
PELVIS 7
1 ULNA 1
1 FEMUR 2
BOTH FEMORA 4

INVOLVED AREA REPRESENTED IN BLACK

Fig. 1

From 1925 through 1949 there were 216 bone tumors (excluding metastatic tumors) seen in the Surgical Pathology Laboratory of the Vanderbilt University Hospital, sixty-eight (31 per cent.) of which were malignant. Thus, the fourteen myelomata composed 6 per cent. of all bone tumors and 20 per cent. of malignant bone tumors. One patient was twenty-nine years old, one was thirty-eight, and the ages of the others ranged from forty-four to eighty-eight years. Eleven patients were males, three were females, and all were white.

The sites of bone involvement are shown in Figure 1. The predominating cell in

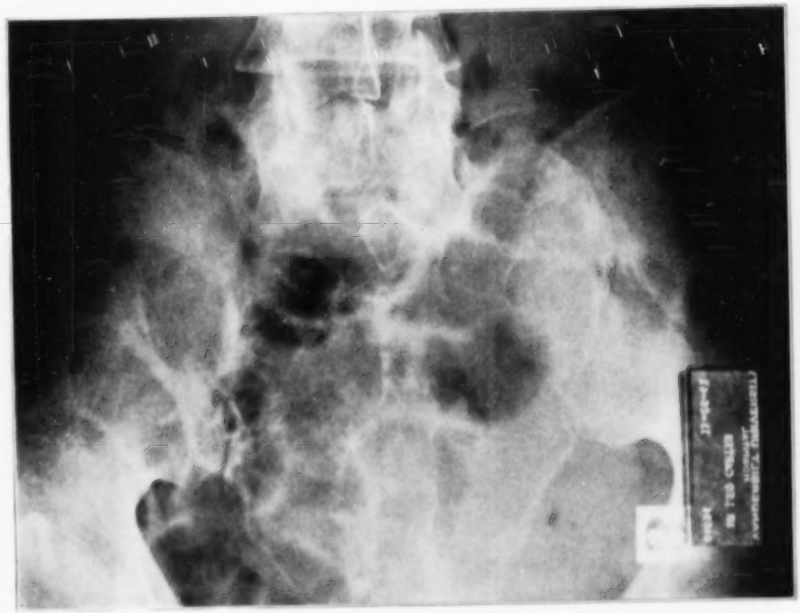


FIG. 2

The roentgenogram of the pelvis at the time of admission in 1941. Before operation, the lesion had been erroneously diagnosed as benign giant-cell tumor.

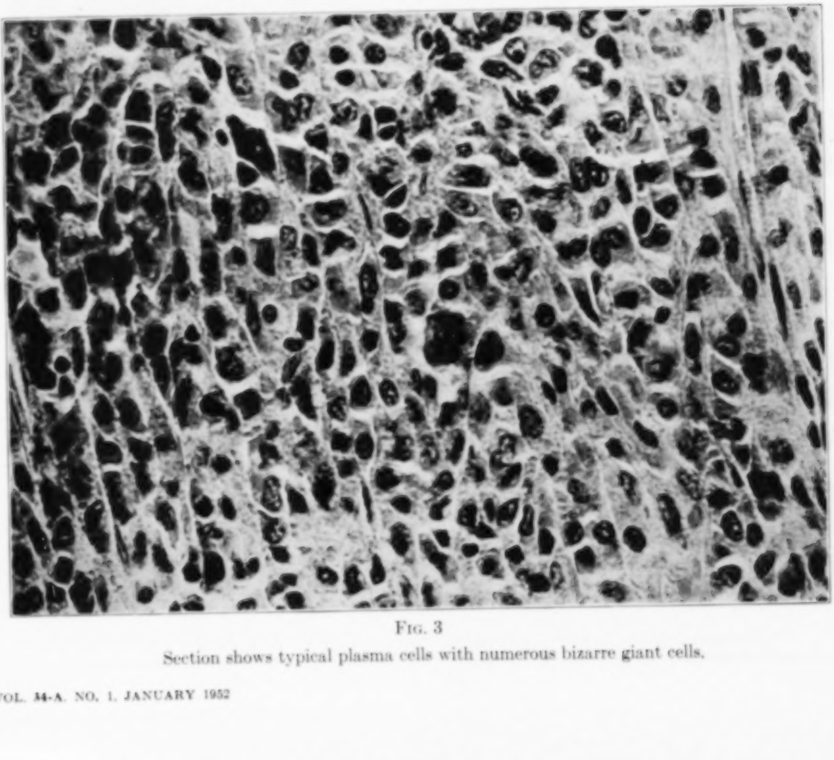


FIG. 3

Section shows typical plasma cells with numerous bizarre giant cells.

eleven patients was the plasma cell. In each of the three remaining patients, the sections showed almost as many reticulum cells as plasma cells. Eight patients died less than six months after admission; four patients lived from twelve to twenty-two months; one is still alive thirty months after admission; and one lived for more than nine years after the diagnosis had been made. The report of the latter patient is presented in detail.

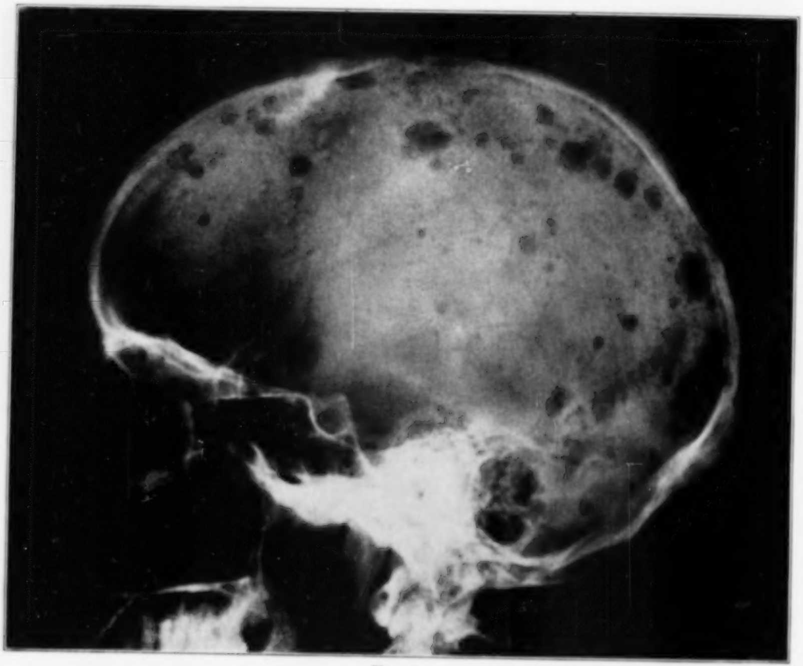


FIG. 4

The roentgenogram of skull shows numerous punched-out areas of rarefaction.

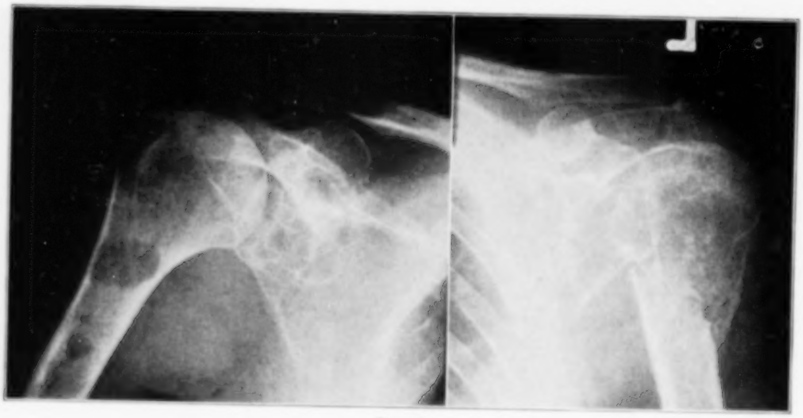


FIG. 5

The roentgenogram shows the pathological fracture of the left humerus after roentgen-ray treatment and subsequent healing. Note extensive lesions in right humerus, scapula, and clavicle.

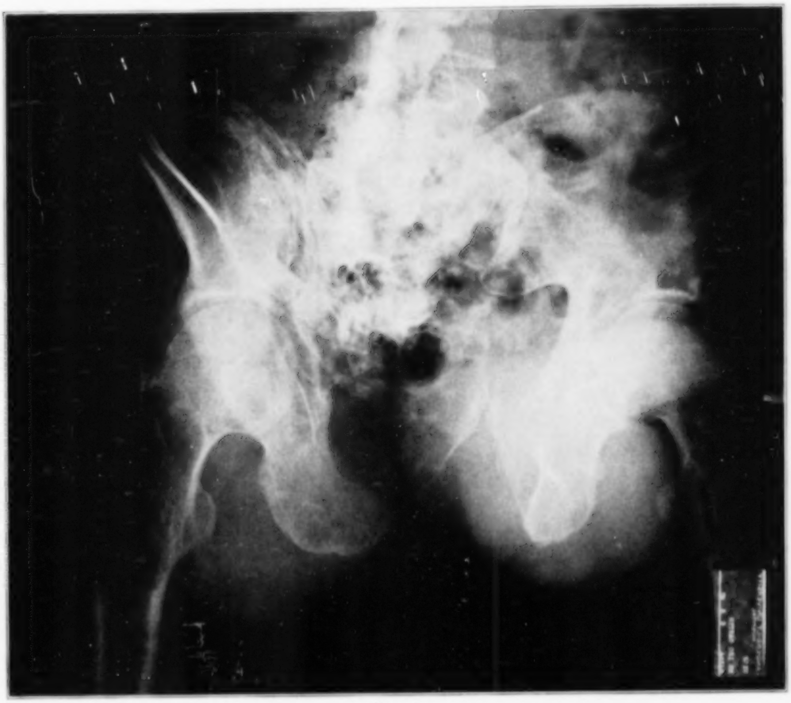


FIG. 6

Fig. 6: The roentgenogram of the pelvis to demonstrate multiple lesions of the sacrum, pubis, ilium, and femora. Note recalcification of the sacrum.

Fig. 7: The roentgenogram of the cervical spine showing collapse of vertebrae.

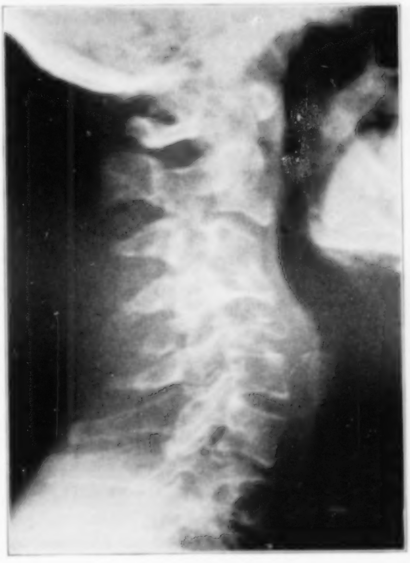


FIG. 7

CASE REPORT

A barber, white, twenty-nine years old (Surg. Path. No. 14660), entered the Vanderbilt University Hospital on December 8, 1941, complaining of pain in the sacral region and right hip. Physical examination revealed a firm, fixed, tender mass overlying the entire sacrum. The roentgenograms (Fig. 2) showed that the major portion of the sacrum and a portion of the fifth lumbar vertebra were involved by a rarefying lesion. The clinical and roentgenographic diagnosis was benign giant-cell tumor. On December 10, 1941, a portion of the thinned outer sacral plate was removed, together with grayish-white, friable, vascular tumor tissue. Microscopic sections* (Fig. 3) revealed a plasma-cell myeloma.

He was given twelve roentgen-ray treatments consisting of 800 r to the mid-line and 2800 r to each of two portals over the sacral area, following which he returned to work.

In March 1943, since the sacral mass was larger, an additional 600 r was given over the sacrum. In

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* The sections were reviewed by Dr. E. W. Goodpasture, Professor of Pathology, Vanderbilt University School of Medicine, who agreed with the diagnosis of myeloma.

November 1946, he received 900 r over the left posterior ribs because of pain. In June 1947, he complained of pain in the cervical region. Roentgenograms revealed rarefaction in the skull (Fig. 4), vertebrae, ribs, shoulder girdle, and pelvis. In view of his excellent general condition, he was given 14,100 r through eight portals.

On January 8, 1948, he was found to have a pathological fracture of the left humerus, and was given 4,000 r through two portals overlying the humerus, glenoid fossa, and scapula. The fracture healed (Fig. 5) and the patient returned to work.

On May 13, 1948, measurements revealed that he had lost six and one-quarter inches in height since the onset of his illness. Total serum proteins on this date were 6.84 grams per 100 cubic centimeters; non-protein nitrogen was 24 milligrams; serum calcium was 10.6 milligrams; serum phosphorus was 3.9 milligrams; and the urine contained no Bence-Jones protein. On May 20, 1948, he returned, complaining of costosternal pain and "popping" of his ribs on deep respiration. He was given a total of 3,600 r over the ribs.

The most recent roentgenograms (Figs. 6 and 7) revealed extensive destructive lesions of the ribs, femora, skull, clavicles, scapulae, humeri, pelvis, right acromion, and bodies of the fifth cervical, sixth and seventh thoracic, and fourth lumbar vertebrae, and the sacrum. Despite the extent of the disease, he was still able to work in July 1950, and on January 20, 1951, he was still not completely incapacitated.

This patient died on May 24, 1951, nine years and five months after the diagnosis of myeloma had been made.

COMMENT

Although it is exceedingly unusual for a patient with myeloma of bone with multiple involvement to survive for nine years, Coley [1] reported survival in one of his patients for eleven years, and stated that he had observed such patients who had lived for five years.

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[1] Coley, B. L.: Neoplasms of Bone and Related Conditions. Their Etiology, Pathogenesis, Diagnosis, and Treatment, p. 328. New York, Paul B. Hoeber, Inc., 1949.

A NEW TYPE OF BRACE FOR THE REHABILITATION OF THE WEAKENED SHOULDER

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In 1947, Dr. Robert L. Bennett of Warm Springs, Georgia, described a method of treatment for the rehabilitation of the weakened shoulder, which embodied the use of an overhead sling.[1] After this method had been in use for some time, it occurred to the authors that the benefits of the overhead sling could be obtained by a brace which would permit a similar range of motion. Since such a brace was not known, an effort was made to develop one.

The problem appeared to be that of designing a joint which would not only permit abduction (elevation) and adduction but would also assist in elevation, and at the same time would limit extension so that anterior subluxation of the shoulder joint would not

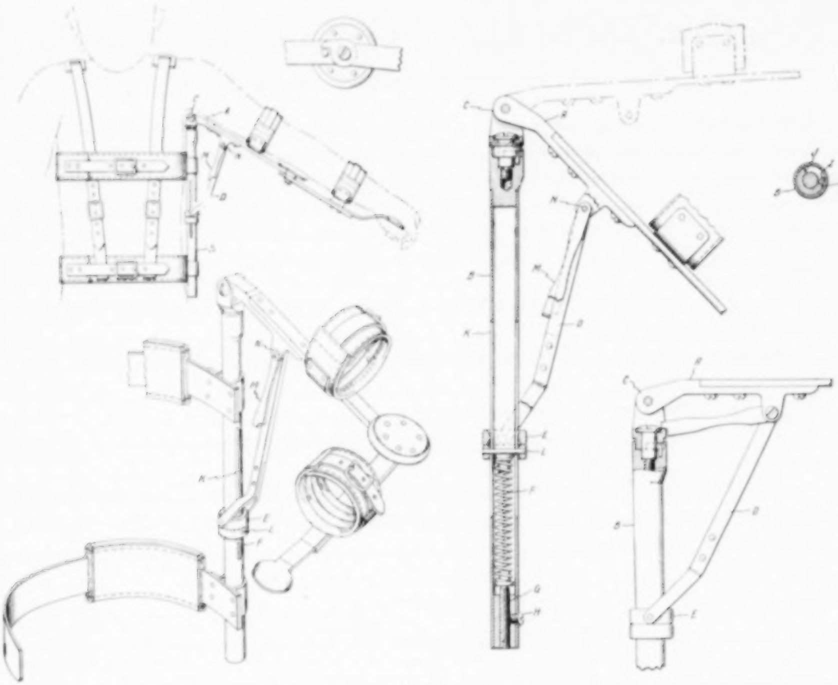

FIG. 1

In the drawing, the axilla joint (*A*) is shown supported for limited universal movement relative to a tube (*B*) secured to the body portion of the brace. Universal movement is obtained by supporting the axilla joint with a universal coupling (*C*) and a strut (*D*). The strut, which regulates the vertical position of the axilla joint relative to the universal coupling, has its lower end connected to a collar (*E*) which rotates about the tube (*B*); the collar, in turn, is biased by a spring (*F*) to support the axilla joint normally in an elevated position.

Tension on the spring (*F*) is regulated by adjusting a screw (*G*) which, in turn, is fixed in any selected position by a setscrew (*H*).

With this structure, the axilla joint has limited powers of abduction and adduction in both the horizontal and vertical planes. Movement in the horizontal plane is limited by a pin (*I*) which is secured to the axilla joint in such a way that it may be engaged with the end walls (*J*) secured to the tube; while movement in the vertical plane is limited by the length of a slot (*K*) in the tube (*B*) through which a pin (*L*) extends to support the collar (*E*).

Another feature of this device is the lock (*M*) which may be engaged (when desired) with a portion of the universal coupling (*C*) to support the axilla joint (*A*) at a position of vertical abduction of 90 degrees. The lock is engaged or released by elevating the axilla joint above the level of 90 degrees and then rotating the lock about a pivot (*N*) either into or out of engagement with the universal coupling.

occur. This has been accomplished by a type of universal joint in the axilla which permits abduction and adduction in various planes. Elevation of the arm to 90 degrees or higher is assisted by an adjustable spring in the hollow tubing of the axillary upright of the brace. The amount of resistance to lowering the arm may be varied by the size of the spring or by adjusting the tension of the spring at the lowest portion of the hollow tubing.

While the use of the sling is limited to a patient in bed or in a chair, the brace permits a much greater range of activity. It may be worn for a much longer period of time and it may also be used in a greater number of routine activities. It is particularly useful for the ambulatory patient. Another advantage in its use is that the tension adjustment of the spring permits varying degrees of assistance to the abductor muscles as function of the shoulder joint returns.

1. BENNETT, R. L.: Convalescent Care of the Weakened Shoulder; with Particular Reference to Use of Overhead Sling. Southern Med. J., **40:** 120–127, 1947.

A BROACHING TOOL TO FACILITATE INTRAMEDULLARY NAILING

BY HOMER H. STRYKER, M.D., KALAMAZOO, MICHIGAN

Intramedullary nailing has become a common method of treatment of fractures of the femur. To lessen the difficulties encountered when inserting the nail, two broaches have been designed—one for the clover-leaf and one for the diamond-shaped nail. They have been used in about a dozen cases with satisfactory results. No complications have been encountered.

Purpose

1. To avoid the difficulties encountered when a nail "jams" and can neither be driven in nor pulled out;
2. To avoid separation of fragments caused by impaction of the nail in the distal fragment;
3. To avoid splitting the shaft of the femur;
4. To avoid the shock of heavy pounding sometimes required to drive in or pull out the nail;
5. To eliminate the necessity for several sizes of nails. One size (11 millimeters) for the diamond-shaped and two sizes (11 millimeters and 10 millimeters) for the clover-leaf shape will suffice for all femora.

Mechanism

The broach cuts a channel through the medullary canal and trochanter the exact size and shape of the nail to be used. It is driven, not turned, into the canal. As it advances,

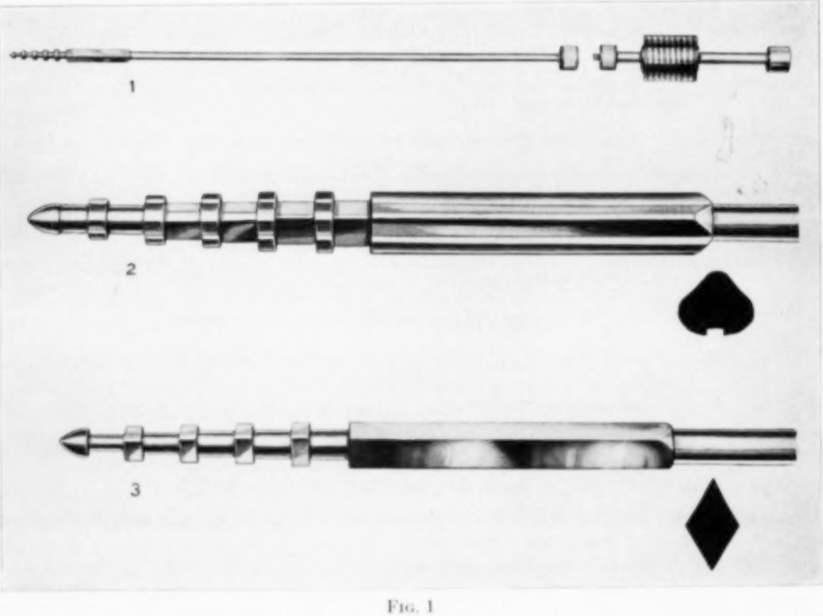

FIG. 1

1. Broach with driver-extractor detached. Actual length of broach nineteen inches; actual length of driver-extractor, eight inches.

2. Cutting end of clover-leaf broach, showing cross section.

3. Cutting end of diamond broach, showing cross section.

each successive tooth cuts a little deeper, the last tooth cutting the channel the exact size and shape of the nail to be used. When the nail is then driven into the femoral canal, it fits snugly but does not bind or become impacted.

Method

The broach is recommended only where the nail is passed retrograde after exposure of the fracture site. It is inserted into the proximal fragment and driven upward through the canal into and through the trochanter. Then it is withdrawn and a nail of corresponding size and appropriate length is inserted into the channel, threaded or eye end first, depending on the type of nail used. With the clover-leaf type, an end plug, inserted in the advancing eye end, is used. This will ensure smooth passage through the gluteal muscles. The nail is driven proximally until the end can be palpated beneath the skin. An incision is then made and the nail is driven on until the lower end is at the fracture site.

The fracture is then reduced and held with a clamp. In elderly patients it is ordinarily possible to drive the nail into the distal fragment without first cutting a channel with the broach. The canal is usually large enough to take the large nails without binding. Accordingly in such cases the nail is driven in the full length, provided it does not bind.

In patients of sixteen to forty years of age, especially with fractures of the middle third, the broach must be used in the distal fragment. To ensure exact positioning, the fracture is reduced as before, held with a clamp, and the nail is driven into the distal fragment a quarter of an inch or more to mark the position of the nail in the canal of the distal fragment. Then the fragments are disengaged and the broach is inserted exactly as marked by the nail. It is driven down through the constricted portion of the canal, stopping three to four inches above the knee joint. Next it is withdrawn, the fracture is reduced again and held with a clamp. The nail is then driven into the distal fragment the estimated distance. If there is doubt as to the proper length, this may be determined by taking an x-ray of the lower end of the nail at the knee, while there is still two inches of the proximal end protruding above the trochanter. At this point the nail may be withdrawn without difficulty and replaced with one of the proper length or, if it is satisfactory, it can be driven in the remaining distance as shown by x-ray. In comminuted fractures the loose fragments are secured by screws or wire before the wound is closed.

In fractures of the upper third of the femur, if the broach is aimed to the lateral side of the canal, it will emerge through the top of the trochanter rather than at the base of the neck, thus facilitating the completion of the operation and the later removal of the nail.

In ununited fractures where there is sclerotic bone filling the medullary canals of the two fragments, it may be necessary to drill a one-quarter inch hole through this bone before the broach is inserted. The fracture may then be fixed with an intramedullary nail and bone grafts may be applied.

TREATMENT OF ACROMIOCLAVICULAR DISLOCATION BY MEANS OF A HARNESS

BY J. HOWARD VARNEY, M.D., JOHN K. COKER, M.D., AND JOHN J. CAWLEY, M.D.
BAKERSFIELD, CALIFORNIA

A treatment of acromioclavicular dislocations by means of an acromioclavicular harness is presented, which the authors have devised and found satisfactory. The harness can be kept at hand, ready for use in the office. One harness works equally well for dislocation of either the right or left shoulder.

Prior to devising the harness illustrated herein, body jackets with straps over the shoulder were used. Another form of treatment used by the authors was that in which the

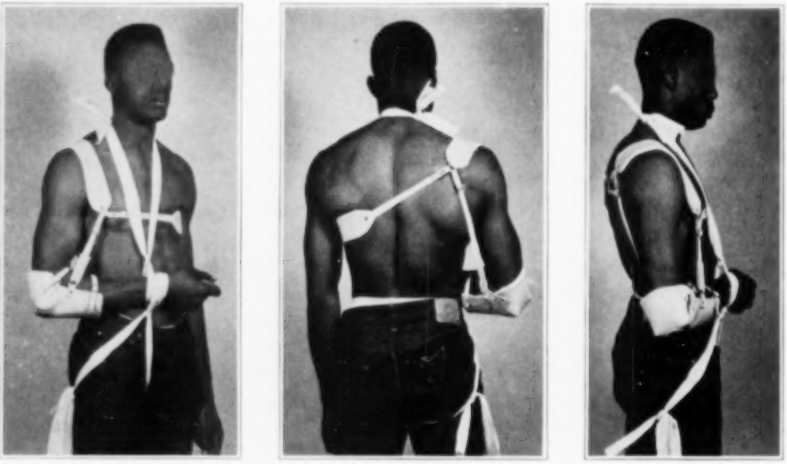

Fig. 1-A Fig. 1-B Fig. 1-C

Photographs showing the acromioclavicular harness

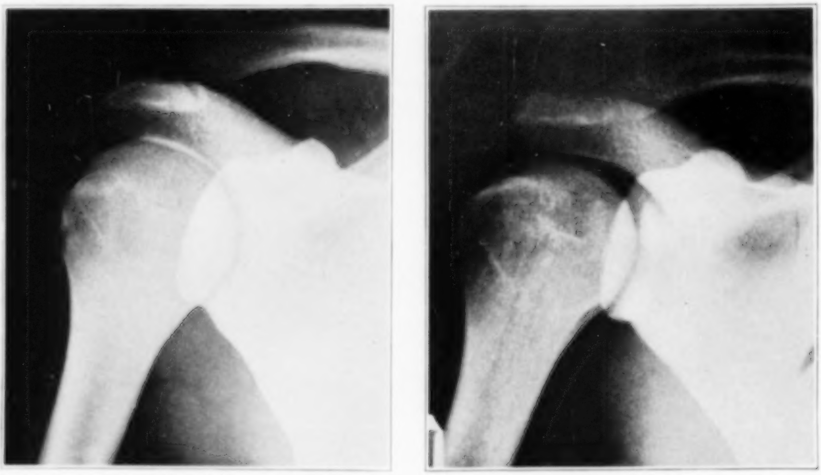

Fig. 2-A Fig. 2-B

X-rays showing acromioclavicular dislocation (Case H. M.) before and after correction.

arm and forearm of the affected side were immobilized in plaster at right angles at the elbow. By means of coat-hanger wire incorporated into the plaster, projections were made medially, front and back, to which a strap was applied to hold the shoulder in position of reduction. Both treatments were tedious and cumbersome; they were uncomfortable for the patient and difficult for the surgeon.

The acromioclavicular harness is easily made. The authors' original harness was made from an automobile-tire inner tube. This gave good results. Later, however, a leather harness with an elastic insert for tightening and a cotton-picker's knee pad at the elbow was evolved (Figs. 1-A, 1-B, and 1-C). This has been used with good results in treating twenty cases. Reduction was maintained and permanent healing was brought about.

On November 4, 1950, H. M., a high-school football player was injured while tackling. Clinical findings and roentgenograms revealed an acromioclavicular dislocation, with the clavicle riding high (Fig. 2-A). The acromioclavicular harness was applied. Upon the removal of the harness in five weeks' time, there was no redislocation. Examination one week later showed that the excellent position obtained at reduction had been maintained (Fig. 2-B). One week later, the patient was able to play without harmful effects in the final play-off game of a football championship series.

NOTE: The following paper was presented by Dr. Klein at the Annual Meeting of The American Academy of Orthopaedic Surgeons. Essentially the same material was published in *The American Journal of Roentgenology and Radium Therapy*, Vol. 66, No. 3, 361–374, September 1951, since it had been presented by Dr. Klein at the meeting of the American Roentgen Ray Society, held in St. Louis on September 26–29, 1950.

Since the paper should be of special interest to readers of *The Journal*, it is being published in the form presented to the Academy. The illustrations are reproduced by permission of *The American Journal of Roentgenology and Radium Therapy*.

Editor

SLIPPED CAPITAL FEMORAL EPIPHYSIS

EARLY DIAGNOSIS AND TREATMENT FACILITATED BY "NORMAL" ROENTGENOGRAMS *

BY ARMIN KLEIN, M.D., ROBERT J. JOPLIN, M.D., JOHN A. REIDY, M.D.,
AND JOSEPH HANELIN, M.D., BOSTON, MASSACHUSETTS

Slipping of the capital femoral epiphysis has evoked a growing interest at the Massachusetts General Hospital during the last forty-six years [2]. In the past many children went untreated for marked slipping. They might have been crippled temporarily in childhood and improved in late adolescence, only to be crippled again in later adult life. For them such reconstructive procedures as arthrodesis of the hip or cup arthroplasty were the alternatives. Experience acquired in more recent times has forced upon us the conviction that the condition should be treated by earlier, more definitive prophylactic procedures,—such as nailing with a Smith-Petersen nail. Therefore, early diagnosis and treatment are of paramount importance.

TREATMENT

Early mild slipping of the epiphysis of less than one centimeter can be nailed *in situ*. Nailing *in situ* is, comparatively speaking, a simple procedure for the orthopaedic surgeon who has been well trained in the lateral nailing of transcervical fractures of the femur. If the slipping remains unrecognized until it amounts to one centimeter or more, the epiphysis should be restored to its anatomical position on the neck before it is nailed. Slipping of short duration can occasionally be reduced by closed manipulation. Most cases with slipping of one centimeter or more, however, are of rather long duration and require open reduction,—that is, exposure of the hip joint, osteotomy through the epiphyseal plate, and accurate replacement of the epiphysis on the femoral neck before nailing. This procedure can be most difficult even for a well trained orthopaedic surgeon. The perfection of technique required comes only after long experience.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 31, 1951.

DIAGNOSIS

Our postoperative results also emphasize the importance of early diagnosis[2,3]. In thirty-five hips in our series which could be nailed *in situ*, the average index of motion was 90 per cent. of normal and the average percentage of normal hip function was 96 after an average follow-up period of thirty-two months[3]. Sixteen patients in our series had remained untreated until the epiphyseal slipping had become marked (one centimeter or more); they required the more difficult operation of open reduction. After an average follow-up period of thirty-three and one-quarter months, the average index of motion was 85 per cent. of normal, and the average percentage of normal hip function was 92. While our patients with marked slipping treated with open reduction showed a good percentage of normal hip motion and function, those seen early with only mild slipping showed even better results.

It may be claimed that patients frequently do not appear for diagnosis and treatment with early complaints and signs but wait until the epiphyseal slipping is so marked that they are noticeably crippled. This is undoubtedly true in some instances, but many of our patients with slipped epiphyses were cases of "missed diagnosis" and had been treated for hip sprains, rheumatism, flat-foot, and psychosomatic manifestations. The existence of the condition should be suspected in any child between six and sixteen years of age who complains of a limp, of pain in the region of the hip, or of both, of pain in the anterior part of the thigh or knee, or who walks with the involved limb in external rotation and presents limitation of internal rotation.

Roentgenographic Technique

Another factor in delayed diagnosis and treatment has been the failure of even those alert to the possibility of slipping to recognize the early stigmata roentgenographically. Although we had previously reported contralateral involvement in only 20 per cent. of cases, a meticulous rechecking of roentgenograms made during treatment and follow-up periods disclosed contralateral involvement in over 40 per cent.

The diagnosis of slipping of the upper femoral epiphysis is made from anteroposterior and lateral roentgenograms of the hips. To facilitate interpretation, standard positions are used, which can be duplicated with minimal technical difficulty in order to furnish comparable views. To obtain a single roentgenogram of both hips, a cassette, fourteen by seventeen inches, is placed transversely beneath the pelvis (Fig. 1). The anteroposterior view is made with the patient supine, the lower extremities extended, and the medial aspects of both feet in apposition, stabilized with sand bags. The hips are then in a neutral position. The tube is placed over the abdomen so that the central ray is projected through the intersection point of the sagittal plane and the transverse plane passing through the centers of the acetabula. For lateral views, the position of the tube remains unchanged; a cassette of the same size is used in the same position as before. The patient remains supine, but the lower extremities are placed in the "frog-leg" position,—that is, the hips are flexed, abducted, and externally rotated, the knees are flexed, and the soles of the feet are in complete apposition. Anteroposterior and lateral views are always taken with both hips shown on each film. Thus, in unilateral cases, comparison of the suspected with the contralateral hip is possible.

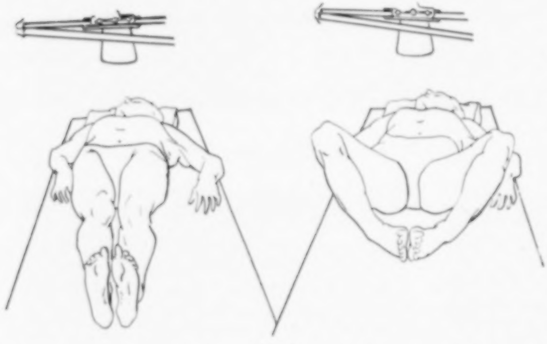

FIG. 1

Standard positions for anteroposterior and lateral roentgenograms. Corresponding views of both hips are included in a single roentgenogram.

With bilateral involvement, however, where there is no "normal" hip for comparison, the early phase of slipping may go unrecognized. In fact, eleven of our first thirty-eight patients had contralateral involvement which remained undiagnosed and untreated. This frequency of bilateral, asymptomatic involvement renders the contralateral hip unreliable as a standard for comparison.

For this reason, a series of roentgenograms of normal hips, both male and female, from birth to maturity * were assembled to serve as a standard for comparison in cases in which epiphyseal slipping is suspected. We believe this series provides a good working basis for detecting rather slight deviations.

* These films were selected from a group of over a hundred children who were free from any nutritional or systemic disease which might affect bone growth or development. The standard technique for bilateral hip roentgenography here described was used throughout.

In addition to roentgenograms of the hips, roentgenograms of the hand and wrist were also made and compared with Todd's standards of skeletal maturation. They confirm Todd's statement that the hip does not lend itself to an accurate assessment of chronological age.

Roentgenographic Characteristics of "Normal" Hips

Study of these roentgenograms of "normal" hips disclosed the following features in the growth of the proximal portion of the femur:

1. In infancy the femoral neck forms an angle with the femoral shaft which approaches 180 degrees. This angle becomes less with age and weight-bearing.

2. Ossification of the head appears to begin between the third and seventh month. This ossification center is ovoid in shape, but after two years of age it gradually assumes the hemispherical contour of the adult head.

3. In the anteroposterior view, at the age of three, the head overhangs the neck so that prolongation of the superior neck line proximally transects a portion of the head. This relationship persists into adult life.

4. The ossification center of the greater trochanter appears between the ages of three and four years.

5. The juxta-epiphyseal portion of the neck after the first year appears slightly cupped in relation to the ovoid head. This relationship is gradually reversed, so that by the age of twelve the metaphyseal portion of the neck has become convex and the overlying head concave.

6. After six years of age, the medial contours of the head and neck describe a continuous arc in the anteroposterior view. In the lateral view, the anterior and posterior surfaces of the neck are concave, and the wide proximal portion of the neck with the head appears spherical.

7. The epiphyseal plate in infancy is wide, particularly in the lateral and medial aspects. With ossification, the plate becomes thinner and the large peripheral gaps are gradually obliterated as the head envelops

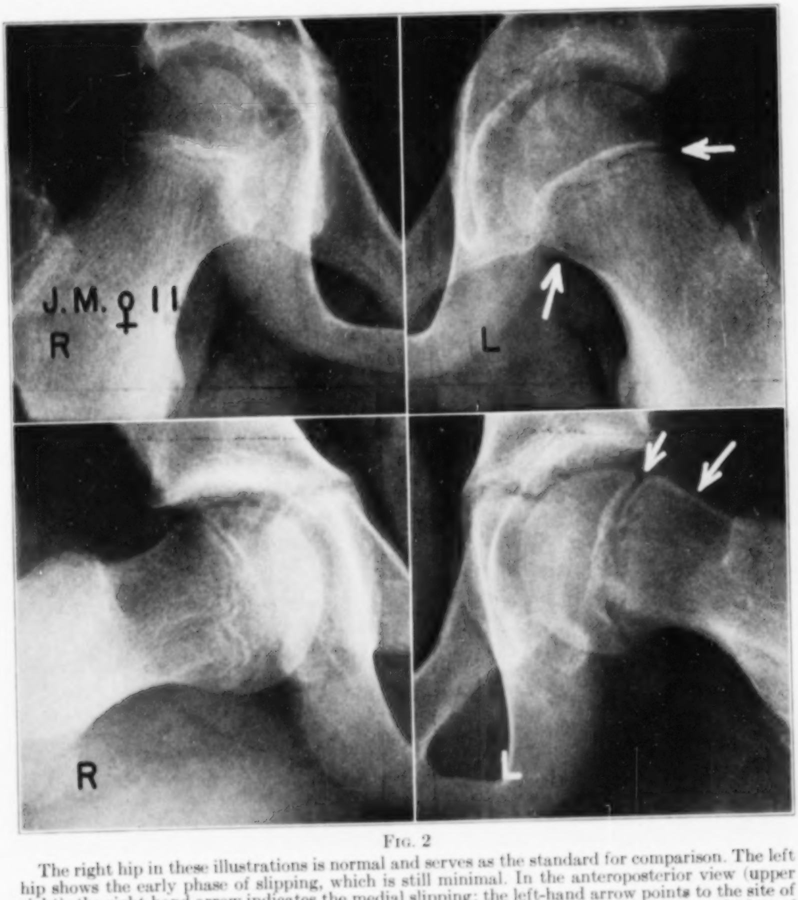

FIG. 2

The right hip in these illustrations is normal and serves as the standard for comparison. The left hip shows the early phase of slipping, which is still minimal. In the anteroposterior view (upper right), the right-hand arrow indicates the medial slipping; the left-hand arrow points to the site of periosteal proliferation. In the lateral view (lower right) the arrow on the right indicates the loss of concavity of the anterior neck line; the left-hand arrow indicates the amount of posterior slipping.

the neck. The central portion of the capital epiphysis appears to fuse first. Fusion of the head and neck occurs between seventeen and twenty years of age in males and one to three years earlier in females.

8. The ossification center of the lesser trochanter appears between the ages of eight and thirteen. The epiphyses of both trochanters usually fuse one to two years earlier than the epiphysis of the head.

9. Therefore, in later childhood and adolescence, a capital epiphyseal plate wider than the epiphyseal plate of the greater trochanter suggests the possibility of a slipped capital epiphysis.

Roentgenographic Characteristics of Slipped Epiphyses

Comparison of cases of suspected and obvious slipping with the "normal" hips brings out certain features of diagnostic importance. In the anteroposterior views of hips in the early stages of slipping (Fig. 2), a wide, irregularly shaped epiphyseal plate, with a sharply outlined metaphyseal border of the head, occurred in 82 per cent. A generalized atrophy of the hip region was observed in 72 per cent. In only 68 per cent. was a downward or medial slipping apparent; this was determined by the failure of the prolonged superior neck line to transect as much of the head as in the "normal" hip. In 71 per cent. there was periosteal proliferation at the inferior junction of the head and neck.

Lateral roentgenograms of epiphyses in the early stage of slipping disclosed posterior or backward displacement of the head in 89 per cent. of the cases, straightening of the anterior neck line in 69 per cent., and periosteal proliferation at the posterior junction of the head and neck in 79 per cent.

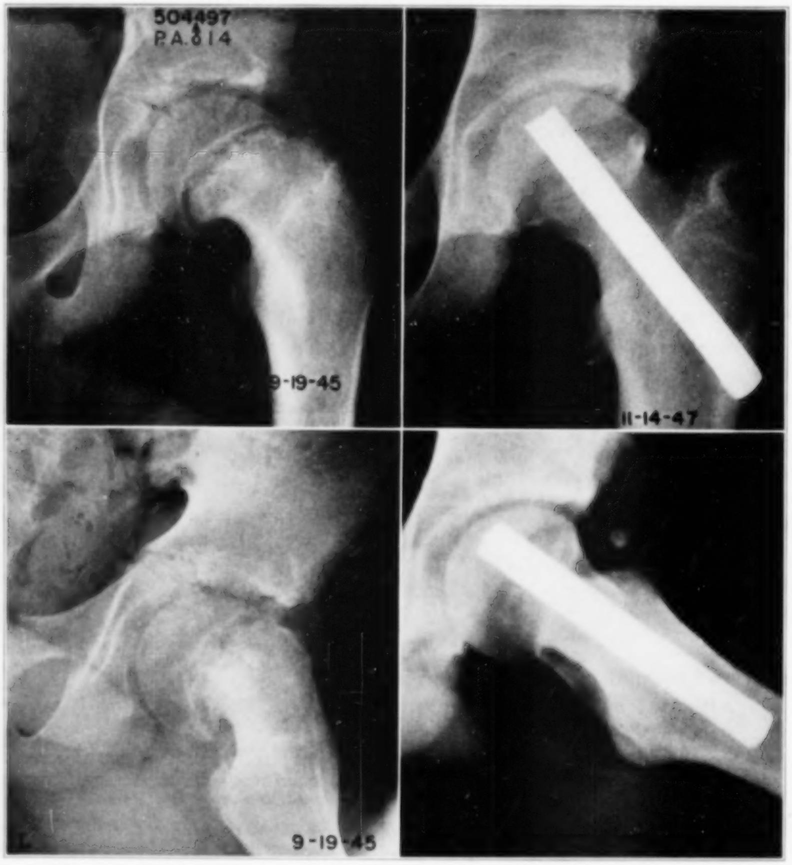

FIG. 3

Roentgenograms made September 19, 1945, show a capital femoral epiphysis with marked slipping of long duration. Roentgenograms made November 14, 1947, two years after open reduction and nailing.

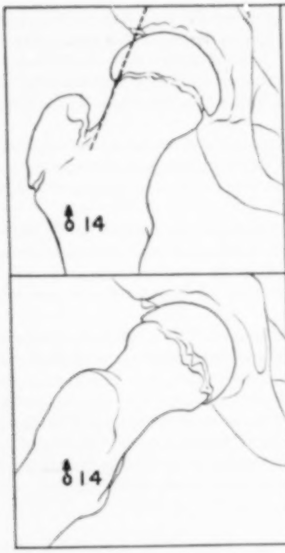

FIG. 4

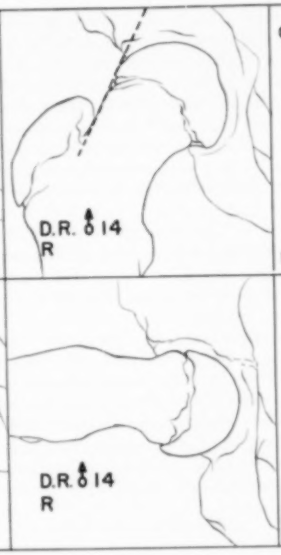

FIG. 5

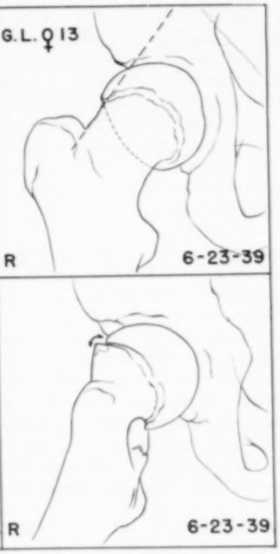

FIG. 6

Fig. 4: Normal hip in a boy aged fourteen serves as standard for comparison.

Fig. 5: Medial slipping of the capital femoral epiphysis in a boy of the same age.

Fig. 6: Posterior slipping of the epiphysis in a thirteen-year-old girl.

Fig. 7: Right hip of M. H., male, aged fifteen. Arrows *A*, *B*, and *C-D* indicate the amount of medial slipping.

Fig. 8: Left hip of R. F., male, aged thirteen. The curved arrow in the lateral view indicates the amount of posterior slipping.

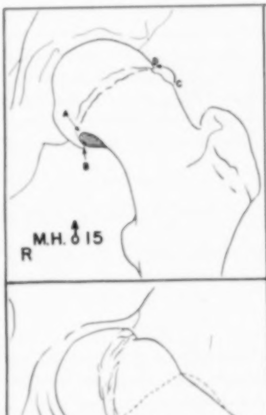

FIG. 7

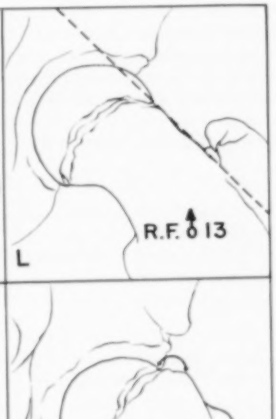

FIG. 8

In the early stages of slipping of the epiphysis, it is not always possible to make a diagnosis from a single roentgenogram. No one view will always show the pathognomonic signs of slipping. It is only an appreciation of the positive changes noted in a comparison of both the anteroposterior and lateral views with "normal" roentgenograms which makes the diagnosis evident.

Meticulous study of cases in which slipping is suspected has not disclosed any so-called "pre-slipping" stage. When, upon examination of one view, it appears that such a situation exists, the other projection invariably also demonstrates some degree of slipping. Those cases in our series showing the earliest phase of slipping which were discovered by periodic x-ray examinations for contralateral involvement always showed a certain amount of slipping, however slight, either in the anteroposterior or lateral view, even before symptoms appeared.

In the later phase of slipping, the neck was found to be shorter and broader on the involved side in 86 per cent. (Fig. 3). The neck contour lost its concavity proximally on its superior and anterior aspects in 94 per cent. The proximal part of the neck at its juncture with the epiphysis was left bare superiorly and anteriorly over an area equivalent to the amount of slipping. Atrophic changes appeared in this region, first as decalcification, later as a molding of the neck to adapt itself to the new position of the head. At the inferior and posterior aspects of the head and neck juncture, overgrowth of bone occurred which, together with the projection of the displaced head, formed a "crow's beak". Obvious descent of the head toward the lesser trochanter was considered to be another criterion of marked slipping.

Slipping of the head may be posterior (Fig. 6), and may be recognized early only in the lateral view; but, in its later stage, it may be seen also in the anteroposterior projection. With further posterior slipping, the head, in the anteroposterior view, is projected through the proximal portion of the neck and appears circular in outline.

Slipping may also be medial (Fig. 5). The early phase of this form of slipping is detectable only in the anteroposterior view. In this view, because of the medial displacement, the superior metaphyseal portion of the neck will be bared and prolongation of the superior neck line proximally will not transect the head. Either type of slipping may predominate in any given case, but as the condition progresses both posterior and medial types of slipping appear.

Recognition of the degree of slipping,—that is, of the amount of displacement of the epiphysis, medially or posteriorly, from its original position on the femoral neck—is also facilitated by comparison with the "normal" hip. The roentgenogram of the "normal" hip clearly indicates where the epiphysis should rest on the neck. In cases in which slipping is suspected, the distance from the margin of the head to that point on the proximal border of the neck where head and neck normally meet denotes the amount of slipping. The degree of slipping is always determined in the view that shows the greater amount of displacement (Figs. 7 and 8). If this is under one centimeter, the slipping is considered minimal, and nailing *in situ* is the treatment of choice. If, however, the slipping is one centimeter or more, open reduction is necessary before nailing.

POSTOPERATIVE CARE

As time goes on, there is a tendency toward improvement roentgenographically as well as clinically [3] following either method of nailing, depending upon the age of the child and the postoperative care. Such care requires periodic x-ray re-examination, at bimonthly intervals at least. These roentgenograms, taken by the standard technique already described, will reveal growth of the head away from the neck and the nail, a change in position of the nail, or any reaction about the nail, whether it be proliferative or absorptive. Since periodic examination includes both hips, it will also be possible to compare the contralateral hip with a "normal" hip and to detect the earliest signs of slipping, even when the patient is otherwise asymptomatic. Also, the patient is warned to return immediately if pain or a limp develops on the opposite side. Follow-up examinations should continue until the epiphyses on both sides have fused.

SUMMARY

1. Detection of *early* slipping of the capital femoral epiphysis permits the simplest satisfactory form of treatment,—namely, nailing *in situ*.

2. The earliest manifestations of slipping become obvious when roentgenograms, taken by a standard technique, are compared with anteroposterior and lateral roentgenograms of "normal" hips of corresponding osseous maturation.

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DISCUSSION

DR. ALBERT FERGUSON, BROOKLINE, MASSACHUSSETS: It is a great pleasure to discuss this paper by Dr. Klein and his associates. They have filled a gap in our knowledge by working out a much needed standard for comparison of slipped epiphyses with normal hips and have reported on the results of early as compared with later surgical treatment.

One is seldom inclined to deplore the attainment of good results, but some of these patients in whom treatment was begun late did so unusually well that one feels somewhat handicapped in continuing to emphasize the need for early treatment. I wonder if, among the patients treated at a late stage of the condition, there were some with poor results who could be used for contrast with those patients who were treated early. If there were such patients I hope Dr. Klein will tell us about them.

Actually, early treatment still needs to be emphasized. It may be said that in some localities patients with slipped femoral epiphyses are not sent to an orthopaedic surgeon soon enough. I wonder if this is not our own fault. I have been informed that excellent results have been obtained by talks before county medical societies and hospital staffs on the subject of early recognition of slipped epiphyses, and that we need to participate in more such meetings.

The standards that have been set up by the authors are excellent for the purpose of estimating the amount of displacement when slipping is definite. There a millimeter makes little difference, but the situation is somewhat different in the determination of minimal slipping. There is, of course, some variation within the normal range, and the limits of variation have not yet been established. There are also variations in alignment in abnormal conditions other than slipping of the epiphysis, such as developmental coxa vara or dislocation of the hip which has been reduced. Similarly in some cases with slipping of the epiphysis, the epiphyseal disc is more inclined to the horizontal than is usual. Such an alignment of the epiphyseal disc tends to produce a variation in the normal alignment of the head.

These difficulties have been encountered by Dr. Klein, as indicated by the following facts: 1. "The proximal part of the neck at its juncture with the epiphysis was left bare anteriorly and posteriorly over an area equivalent to the amount of slipping". 2. In 68 per cent. of the authors' cases, no part of the head was transected by a prolongation of the superior neckline proximally, or at least a smaller segment was transected than in the normal hip. While a smaller segment of the head was transected, obviously the neck was not bared and the bared portion of the neck could not be a basis for measurement. With such symptoms there may be some question as to whether slipping is present or not; some may interpret them as manifestations of a pre-slipping stage and others as definite slipping. Nowadays this distinction is not particularly relevant. These patients are usually treated by bed rest with only a tentative diagnosis, and slipping in their case does not go further. There remains, however, the theoretical problem: When a pathological condition which is not due to trauma develops in the hip of a patient who has been recumbent for treatment of the contralateral hip, we know that something must have preceded it. We may not be able to recognize a pre-slipping stage, but we all know that one exists.

Dr. Robert W. Johnson, Jr., Baltimore, Maryland: It is difficult to discuss a paper when the authors have really said the last word on the subject. Dr. Klein and his coworkers have very wisely limited their objectives and concentrated on them alone, and I feel that they have not only proved their point but have defended it against any possible attack. There is undoubtedly much we would still like to know about slipped epiphyses, but problems of etiology, pathology, and prognosis are essentially beyond the scope of this paper, and the authors are striving only to bring out two important points: (1) early diagnostic roentgenographic findings and their recognition, and (2) the unexpectedly high incidence of involvement of the contralateral hip—40 per cent., as opposed to the usually accepted figure of 20 per cent. Both of these points are of real importance and should be heeded in order to save many a patient from permanent disabling deformity of both hips.

Certainly I have nothing to quarrel with or to add to this presentation. I do not believe in discussing a paper so wisely and carefully limited by the authors in terms of the more debatable phases of the problem as a whole, such as cases with old slipping and extensively displaced epiphyses, and how best to deal with them.

However, I should like to add a point which the authors did not have time to express, but with which I know they agree: In all manipulations or operative procedures undertaken to reduce displacement and to restore alignment, the greatest care and gentleness must be exercised to prevent further trauma or circulatory disturbance to the epiphyseal fragment.

I think that Dr. Klein and his associates, in bringing a phase of our ever-present diagnostic and therapeutic problem so clearly and graphically before us, have rendered a real service to the Academy, especially to its younger and less experienced members.

News Notes

Part II examinations of **The American Board of Orthopaedic Surgery** will be held in Chicago, Illinois, on January 23, 24, and 25, 1952. Further information may be obtained from the Secretary, Dr. Harold A. Sofield, 122 South Michigan Ave., Chicago.

A joint meeting of **The American Orthopaedic Association** and the **British Orthopaedic Association** is scheduled to be held in London, June 30 to July 5, 1952. The meetings will be held at the William Beveridge Hall at the University of London. A very interesting scientific and entertainment program is being planned by the several program committees and the Committee on Arrangements.

Members of The American Orthopaedic Association and their families and guests who are planning to attend the meeting are urged to make their hotel and travel reservations early. Many have already made arrangements to sail on the Ile de France, leaving New York on June 20 and arriving in time for the meeting.

The Seventh Annual Meeting of the **American Society for Surgery of the Hand** will be held at the Palmer House, Chicago, Illinois, on Friday, January 25. The program includes the following papers:

Deformities of the Hand Incident to Pathology of the Extensor and Intrinsic Muscle Mechanisms
J. Leonard Goldner, M.D., Durham, North Carolina (by invitation)
Discussion: S. Benjamin Fowler, M.D., Nashville, Tennessee
L. D. Howard, M.D., San Francisco, California
An Evaluation of Skin Grafts for Hand Coverage
S. M. Dupertuis, M.D., Pittsburgh, Pennsylvania
Discussion: W. Brandon Macomber, M.D., Albany, New York
Harvey S. Allen, M.D., Chicago, Illinois
Arthrodeses of the Hand—Part III. A Wrist Arthrodesis
William H. Frackelton, M.D., Milwaukee, Wisconsin
Discussion: Harold B. Boyd, M.D., Memphis, Tennessee
T. Campbell Thompson, M.D., New York, N. Y.
Luxation of the Distal Radio-Ulnar Joint
Frederick Lee Liebolt, M.D., New York, N. Y. (by invitation)
Discussion: Donald B. Slocum, M.D., Eugene, Oregon
Surgical Principles for Reconstruction of Congenital Hand Deformities
Robert M. McCormack, M.D., Rochester, New York
Discussion: Arthur J. Barsky, M.D., New York, N. Y.
William H. Frackelton, M.D., Milwaukee, Wisconsin
Tendon Transplants in Median and Ulnar-Nerve Paralysis
Daniel C. Riordan, M.D., New Orleans, Louisiana
Discussion: Sterling Bunnell, M.D., San Francisco, California
Reconstructive Surgery for Ulnar-Shaft Defects in Growing Children
Carmelo C. Vitale, M.D., New York, N. Y. (by invitation)
Discussion: Mather Cleveland, M.D., New York, N. Y.
Leo Mayer, M.D., New York, N. Y.
Intramedullary Fixation of the Hand and Fingers
Frederick vom Saal, M.D., New York, N. Y. (by invitation)
Discussion: J. William Littler, M.D., New York, N. Y.
William Metcalf, M.D., New York, N. Y.
Problems with Trauma to the Hand
J. Edward Flynn, M.D., Boston, Massachusetts
Discussion: Sumner L. Koch, M.D., Chicago, Illinois
Vinton E. Siler, M.D., Cincinnati, Ohio
Fracture of the Carpal Navicular
Carruth J. Wagner, M.D., Staten Island, New York
Discussion: James K. Stack, M.D., Chicago, Illinois

The National Society for Crippled Children and Adults will hold its annual convention in San Francisco, October 25 through 30, 1952.

The Nineteenth Annual Meeting of **The American Academy of Orthopaedic Surgeons** will be held at the Palmer House, Chicago, from January 26 to January 31, 1952, under the presidency of Dr. Joseph S. Barr. Registration will begin at 9:00 o'clock Saturday morning, January 26. Dr. Lyman Smith and Dr. John R. Norcross advise that the scientific and technical exhibits will be ready for inspection Saturday morning. During the afternoon, the Audio-Visual Program will be presented under the direction of Dr. Frank E. Stinchfield. This program will be continued on Sunday morning.

The Instructional Courses will be held on Sunday afternoon and continue until noon on Monday. Dr. Charles N. Pease and his committee have organized the largest number of courses in the history of the Academy and they will be presented by a distinguished faculty. On Monday evening at the Instructional Course Dinner the "Information Please" program will be featured.

An excellent scientific program, including papers by three foreign guests, has been prepared by the Program Committee, Dr. George O. Eaton, Chairman. The Scientific Program will occupy the afternoon and morning sessions from Monday afternoon to Thursday noon. New members will receive their certificates of membership at the scientific session on Monday afternoon.

The Annual Banquet of the Academy will be held on Wednesday evening. Thursday evening will be reserved for alumni dinners and other special groups.

The Louis Lefkoe Memorial Foundation offers a prize of $500.00 for the most worth-while original contribution to the medical knowledge of Cerebral Palsy.

The paper may cover any aspect of the subject,—such as pathogenesis, biochemical knowledge, pathology, diagnosis, or treatment.

The paper is to be submitted to the Trustees of the Foundation on or before September 1, 1952. The prize is open to anyone who can contribute to the medical knowledge of the subject.

The *Bulletin on Rheumatic Diseases* has become the official publication of the national organization of the **Arthritis and Rheumatism Foundation.**

A booklet on *Home Care in Rheumatoid Arthritis* has recently been issued by the Medical and Scientific Committee of the Arthritis and Rheumatism Foundation. This booklet contains instructions for patients with arthritis. It is available to physicians only and may be ordered from the New England Chapter, The Arthritis and Rheumatism Foundation, 201 Devonshire Street, Boston 10, Massachusetts.

The Foundation of the American Society of Plastic and Reconstructive Surgery announced the winners of this year's awards in its Competitive Essay, at the Annual Meeting of the Society held in Colorado Springs, October 30 to November 1, 1951.

Dr. Richard B. Stark, New York City, won a scholarship award for his essay:
"The Cross-Leg Flap Procedure".

The following three received Honorable Mention for their essays:

Dr. Kathryn Lyle Stephenson, Santa Barbara, California
Essay: "The Production of Ectopic Cartilage".

Dr. Michael N. Tempest, Leeds, Yorkshire, England
Essay: "Cross-Finger Flaps in the Treatment of Injuries to the Finger Tip".

Dr. Allyn J. McDowell, North Hollywood, California
Essay: "Mass Treatment of Burns in Atomic Warfare".

For full particulars pertaining to the 1952 Competitive Essay write to The Award Committee, in care of Jacques W. Maliniac, M.D., 11 East 68th Street, New York 21, N. Y.

The International Congress of Physical Medicine, organized by the British Board of Management of the International Federation of Physical Medicine, will be held in London from July 14 through July 19, 1952, under the presidency of Lord Horder.

The meetings of the Congress will be reserved for matters dealing with the clinical, remedial, prophylactic, and educational aspects of physical medicine and the diagnostic and therapeutic methods employed in physical medicine and rehabilitation.

In addition are planned technical, scientific, and historical exhibitions, as well as a full program of social events for members and associate members. Arrangements for visits of scientific and historical interest both in London and in the country are being made for the week of the Congress and the week following the Congress.

Applications for the provisional program should be addressed to the Honorary Secretary, A. C. Boyle, M.D., International Congress of Physical Medicine (1952), 45 Lincoln's Inn Fields, London, W.C. 2.

The Sixth Annual Meeting of the **New Jersey Orthopaedic Society** was held on October 12, 1951, at the Betty Bacharach Home in Longport, New Jersey. The following officers were elected:

President: Dr. Raphael R. Goldenberg, Paterson
President-Elect: Dr. Paul J. Finegan, Trenton
Secretary: Dr. William Kruger, Newark
Treasurer: Dr. Harold T. Hansen, South Orange

The following papers were presented:

Osteochondrosis of the Hip—Perthes Disease: Dr. John Naame (by invitation)
Adolescent Deficiency Disease: Dr. Jarvis M. Smith
Observations on Intervertebral-Disc Injuries: Dr. Paul J. Finegan
Arthrodesis of the Wrist: Dr. A. M. Rechtman
Resection of Elbow Joint for Arthritis: Dr. Robert J. Neville
Functional Anatomy of the Hand (moving picture): Dr. Robert J. Neville

Discussion: Dr. Samuel Kleinberg, New York City; Dr. Henry Briggs, East Orange; Dr. Raphael R. Goldenberg, Paterson; Dr. Harold W. Smith, Orange; and Dr. Alfred R. Shands, Jr., Wilmington, Delaware.

The Thirty-sixth Annual Meeting of the **Società Italiana di Ortopedia e Traumatologia** was held in Rome, on October 20, 21, 22 at the Orthopaedic Hospital of the University, under the presidency of Prof. C. Marino-Zuco. The principal subject under discussion was: "Means of osteosynthesis in modern traumatology" with an official report by Prof. C. Marino-Zuco and his coworkers, Drs. M. Pancino, V. Pietrogrande, A. Rampoldi, M. Ascoli, and E. Tranquilli-Leali. Eighty-four papers were presented on this subject and twenty-three on different subjects.

The Thirty-seventh Annual Meeting of the Società Italiana di Ortopedia e Traumatologia will be held in Genoa, in October 1952, and the principal subject to be discussed will be: "Surgery of the Paralytic Shoulder".

CUSTIS LEE HALL

1888–1951

On Saturday, November 10, 1951, Dr. Custis Lee Hall died in his sixty-fourth year in Washington, D. C.

Dr. Hall was born in Washington, in 1888. He attended the George Washington University, being graduated from the Medical School in 1912. After a year's internship at the Garfield Memorial Hospital, Washington, he trained in orthopaedic surgery at the Massachusetts General Hospital, and then practised for one year in association with the late Dr. E. G. Brackett in Boston. Joining the first Orthopaedic Unit under the direction of Dr. Goldthwait, he went to England in April 1917, and served there in Wales, and finally in Edinburgh where he worked under Sir Harold Stiles and Sir Robert Jones. There was a three-months' period in Savenay, France, where he was in charge of the Orthopaedic Service. In September 1918, he resumed private practice in Washington.

Dr. Hall had hardly established himself in practice when he was injured in the famous Knickerbocker Theatre catastrophe and thereafter never completely recovered the use of his right hand. He was fortunate, however, in that he had always been trained to use both hands, and it may be recalled that he used to draw with one hand and at the same time write with the other on the blackboard for his students. This dexterity was a great help to him, and he was able to do a great deal of his surgery with his left hand.

Dr. Hall was Clinical Professor of Orthopaedic Surgery at George Washington University from 1919 to the time of his death in 1951. During his lifetime he was Chief of the Orthopaedic Staff at the Children's Hospital, the George Washington Hospital, Garfield Memorial Hospital, and Doctors Hospital. He was consultant in orthopaedic surgery to the Veterans Administration Hospital from 1919 to 1946 and to the U. S. Naval Hospital at Bethesda, Maryland, from 1946 to 1951. Many orthopaedic surgeons owe their start in practice in Washington to Dr. Hall; for he gave them their early training in his office and at his various clinics.

He was a member of The American Academy of Orthopaedic Surgeons, of the American Medical Association and the District of Columbia Medical Society. He was a past president of the George Washington Medical Society, the Washington Orthopaedic Club, the Orthopaedic Guild, the Crippled Children's Medical Society, and the Arthritis and Rheumatism Foundation of the District of Columbia. He was also past president of the International College of Surgeons, United States Chapter, and an honorary member of the Kiwanis Club, in charge of the care of the Crippled Children's program.

Dr. Hall led an extremely active life and worked very hard for his success, seldom leaving his practice for long. However, he was a careful student of photography, especially the taking of moving pictures in which he excelled.

His generous and unfailing contributions to the care of the cripple and to the advancement of orthopaedic surgery, not only in time and energy, but in wisdom, knowledge, and skill, have left a deep impression, at home and abroad, on the memories of a host of friends and patients.

Book Reviews

REST AND PAIN, Ed. 6. John Hilton, F.R.S., F.R.C.S. Edited by E. W. Walls, M.D., Ch.B., B.Sc., and Elliot E. Philipp, M.A., M.B., B.Chir., M.R.C.S., M.R.C.O.G., in collaboration with H. J. B. Atkins, D.M., M.Ch., F.R.C.S. Philadelphia, J. B. Lippincott Company, 1951. $10.00.

There are a few old books of great importance which either are forgotten or are drowned in the stream of new literature and present-day problems. Some of these older books played an important role in their day, for they established a basis for subsequent development in certain branches of medicine. These remain important not only as documents of historical interest but also as instruments for further development in medicine and surgery and as sources of better understanding of basic concepts. Such a book is *Rest and Pain*.

For the orthopaedic surgeon, *Rest and Pain* is of special interest; it had great influence on some of the pioneers of orthopaedic surgery. Hugh Owen Thomas, as was recently shown by H. Winnett Orr, developed under the direct influence of Hilton's work. *Rest and Pain* had been considered indispensable and, since it was first published in 1863, it has been reprinted many times; but in our time it has been long out of print. Under the editorship of Walls and Philipp, the work has now been published in a sixth edition.

The importance of the work is to be found in its teaching of gentleness in the practice of surgery and a "delicacy of approach to the problems of healing". The book reflects Hilton's anatomical logic, clear thinking, and his search for simple generalizations of which Hilton's law is an excellent illustration. Both the novice and the mature orthopaedic surgeon will find Hilton's work of great value.

The publishers deserve high praise for publishing this ever-timely work in such a beautiful and accessible form.

INJURIES TO THE ANKLE. J. Grant Bonnin, M.B., B.S. (Melbourne), F.R.C.S. (England). New York, Grune and Stratton, 1950. $9.75.

This is a very thorough "fracture book", complete in almost every detail concerning injuries to the ankle, including trauma to the ligaments, the articular surfaces, and to the bones. Great attention is given to the mechanism of production of the various types of fractures of the ankle—the abduction, adduction, and bursting fractures—as well as to epiphyseal injuries. This analysis of the mechanism of injury is traditionally peculiar to the ankle in the writings of many authors, particularly those of Ashurst in the early 1920's. Whether this detailed analysis in the text is justified is questionable, since most experienced surgeons will "reduce" the fracture without attempting to retrace the steps required to produce the injury.

Two of the most important and interesting parts of this worth-while book are the chapters concerning: (1) the lives of the great surgeons who have been responsible for much of our knowledge of ankle injuries,—Pott, Dupuytren, Ashurst, and others; and (2) the functional anatomy of the ankle joint.

The discussion of roentgenography of the ankle is well done and contains several practical points on the technique of obtaining the most effective x-ray films. An extensive bibliography is appended to each chapter.

In all probability this is the most complete work on ankle fractures in the English language and should be accessible to every fracture student and practitioner.

TRAITÉ D'ANATOMIE HUMAINE. Tome I: Ostéologie, Arthrologie, Myologie. Tome II: Membres supérieur et inférieur. Prof. Georges Paturet. Paris, Masson et Cie, 1951.

In Prof. Paturet's comprehensive anatomy, the first two volumes of which have now appeared, the rigid distinction between anatomy and physiology characteristic of earlier texts has been discarded. The older anatomies were written for the most part from the viewpoint of the dissecting room, consisting of descriptions of lifeless structures; the newer anatomies take the operating or consulting room as their point of departure. In this splendid work the reader is ever aware of the relation of structure to function.

On the whole, the author's systematic approach to his subject will be found vivid and illuminating. Bibliographical references are given in footnotes throughout the text, and the author frequently presents a brief summary of past and current opinion on controversial matters or on subjects about which we do not yet have sufficiently accurate and detailed information.

Volume I of the projected six-volume work deals with osteology, arthrology, and myology; Volume II deals with the upper and lower extremities. The four volumes to follow will deal with the circulatory and respiratory apparatus, larynx, thyroid, parathyroid, and thymus glands (Vol. III); the central and sympathetic nervous systems, the neuro-endocrine system, and neurology (Vol. IV); the visual and auditory apparatus, urogenital system, pelvis and perineum, mammary glands, skin and suprarenal glands, and paraganglia (Vol. V); and with the digestive apparatus, peritoneum, and lymphatic system (Vol. VI).

The illustrations, many of them partly or wholly colored, will be found particularly helpful by the student. Each volume has a comprehensive index.

Surgeons, instructors, and students will undoubtedly find M. Paturet's work a valuable addition to the literature which they will frequently wish to consult.

Post-Graduate Lectures on Orthopedic Diagnosis and Indications, Vol. II. Arthur Steindler, M.D., F.A.C.S. Springfield, Illinois, Charles C. Thomas, 1951. $6.00.

Volume II of this series of four volumes of *Post-Graduate Lectures on Orthopedic Diagnosis and Indications* meets the high standard that characterizes Volume I. The two broad subjects presented in Volume II are (1) Paralytic Disabilities and (2) Static Disabilities.

Just as we would want him to do, the author discusses his own personal concepts of these subjects as they have been evolved through a long and vast clinical experience.

In Part I, under the Paralytic Disabilities, there are excellent discussions of poliomyelitis, paralytic scoliosis, and spastic paralysis. Considerably more material is presented than one would ordinarily expect to find in an orthopaedic treatise. The pathology and pathogenesis are well outlined, and the pathological anatomy and pathogenesis are correlated with the clinical features of the conditions. The causes of failure in treatment are critically and frankly analyzed. Details of operative technique are not, however, included.

The section on Static Disabilities includes discussions of lumbosacralgia, idiopathic scoliosis, internal derangements of the knee, and static deformities of the foot and ankle. The section on lumbosacralgia is an outstanding one, in which the author presents his well-known procaine test. Idiopathic scoliosis is discussed in detail; Steindler has been an authority in this field for three decades.

This volume is not written for the orthopaedic surgeon alone, but it is written as well for the internist, the pediatrician, and all others who treat musculoskeletal disorders.

Dr. Steindler, one of the greatest teachers of orthopaedic surgery of our time, deserves commendation and thanks for making these lectures available to us.

Lehrbuch der Röntgendiagnostik. 5. Auflage, 4. Lieferung: VIII. H. R. Schinz, W. E. Baensch, E. Friedl, und E. Uehlinger. Stuttgart, Georg Thieme, 1951. 84 German marks.

The Fourth part of the German edition of the Textbook of Diagnostic Roentgenology by Schinz and his colleagues deals primarily with the conditions and diseases of the spine and skull, the soft tissues, and related problems. As in the preceding volumes, the well-written and interesting text is illustrated by numerous sketches, diagrams, and excellent reproductions of roentgenograms. The unusual quality of the roentgenograms can be explained by the fact that they have been reproduced in the positive rather than in the negative phase, which allows considerably greater detail than is possible in the usual type of illustration.

The sections dealing with the spine and the skull are prefaced by good descriptions of the anatomy, the development, and the many variations from normal. Various chapters are devoted to abnormalities and malformation of the spine, postural changes, and deformities; those on degenerative arthritis and ankylosing diseases are of particular excellence.

Fractures, dislocations, and secondary conditions due to trauma are extensively discussed and illustrated. The chapters dealing with the bone manifestations due to tumors of the spine and cord are perhaps somewhat brief. The subject seems to the reviewer to warrant discussion at greater length.

Lindgren's section on myelography, although interesting and versatile in many aspects, does not give to this type of examination the degree of importance that is attached to it in this country. The chapter is confused and incomplete, particularly in regard to a practical description of the procedure. In this country its use in many institutions has become almost routine in diagnosis when a ruptured disc is suspected. To many roentgenologists, orthopaedic surgeons, and neurosurgeons, the employment of myelography in the examination of the spine is as essential as is the barium study of the gastro-intestinal tract to enterologists and their roentgenologist consultants.

The sections on changes in the skull due to trauma are excellent and should be of particular interest to the surgeon of trauma. The mechanisms which precipitate the various types of fracture are well presented. Most of the diseases affecting the bony structures are comprehensively discussed and are well illustrated. The roentgenographic manifestations of intracranial pathology, however, are somewhat sketchily described and the material is not so well coordinated as is that in other parts of the book. In their nature, however, such conditions are so many and so complicated that a satisfactory integration of the various problems they present would require considerably more space than can be allotted to them in an ordinary textbook of general roentgenology. These same criticisms apply as well to the chapters on the roentgenography of the accessory sinus, mastoids, and the eye, all of which are well but not abundantly covered.

Encephalography, ventriculography, and angiography are given appropriate space in the text; techniques are described and illustrated with examples of the most common pathological conditions for which the respective methods are of value. Accompanying tables of the distribution of the arterial and venous systems of the skull and brain with the many variations from normal will greatly aid the reader in his understanding of these complicated procedures.

A short but excellent chapter dealing with the roentgenographic demonstration of the jaw, the teeth, and the eye, clearly describing the various methods for the localization of foreign bodies around the eyeball, deserves mention.

Special mention must be made also of the chapter on the demonstration of soft-tissue lesions, a problem of great importance to the roentgenologist as well as to the surgeon. The differentiation of fatty and gaseous shadows under various conditions, the pathological densities and many manifestations of abnormal calcification in soft parts are well portrayed. Other brief chapters cover methods for demonstrating fistulae, glandulography with particular reference to the breast and salivary glands, and arteriography and venography of the extremities and adjacent parts.

The book concludes with tables of the topographic distribution and differential diagnosis of all skeletal diseases, with reference to localization, age and sex incidence, symptomatology, and histological findings.

In *4. Lieferung* of this textbook on diagnostic roentgenology, another valuable edition has been offered to the roentgenologist and others who are interested in the problems under discussion. The standards of excellence in text, quality of print, illustrations, and bibliography set by the preceding volumes have been maintained. (One of the authors, Baensch, has assured the reviewer that, in the forthcoming American edition of the work, the bibliography will be enlarged and particular attention will be paid to the literature in the English language. The first book of the American edition, a translation of the *1. und 2. Lieferungen* is now available in this country and it is expected that the second book will be ready for circulation before the end of the year.)

Once again Schinz and his co-workers are to be congratulated on making this material available.

ROENTGEN-DIAGNOSTICS, Vol. I, Skeleton (Part 1). H. R. Schinz, W. E. Baensch, E. Friedl, and E. Uehlinger. First American Edition (Based on Fifth German Edition). English translation arranged and edited by James T. Case, M.D., D.M.R.E. New York, Grune & Stratton, 1951. $36.00.

The appearance of the first volume of an English-language translation of the great *Lehrbuch der Röntgendiagnostik* fills a long-felt need. Such a translation had been previously planned; however, the appearance of a greatly revised and a thoroughly augmented German edition and the outbreak of World War II made this both unfeasible and impossible. When plans were made for a Fifth German Edition of the *Lehrbuch der Röntgendiagnostik*, arrangements were made to issue, concurrently, an American edition.

Volume I of the American Edition is a translation of the first two installments of the German work. (These installments were reviewed in The Journal for October 1950 and April 1951, respectively.) The first section of the book, nearly 100 pages, deals with the theory of the roentgen image, protective measures against damaging exposure to x-rays, fine structure analysis, the possibilities and limitations of the roentgendiagnostic method, and examination procedures. While this material has been written by specialists, it is not addressed to them exclusively; the chief purpose of the work is to provide the physician and the medical student with the fundamentals of the speciality in the hope that readers of the volumes will be persuaded that roentgenological diagnosis is indispensable in research, in practice, and in teaching.

The bulk of Volume I is devoted to the roentgenographic examination of the skeletal structures. Under this heading are discussed in rich detail such subjects as bone fractures and the healing of bone fractures, aseptic necrosis, inflammatory bone diseases, and hereditary diseases with bone changes. Each section is concluded with a bibliography which cites the American as well as the foreign literature.

The translation itself is an interesting one, for the translator's intention is not to reproduce the German edition slavishly translated word for word, but rather to "transfer" the German thought to an English text, thereby retaining much of the spontaneity and clarity of the original.

The publishers are to be congratulated upon the excellence of the printing and the reproduction of illustrations; they are to be thanked for making available to an American readership one of the indispensable works of medical literature.

ARTHRO-SYPHILIS CONGENITA TARDIVA ET ACQUISITA ET ARTHRO-METASYPHILIS. Halfdan Sundt, M.D., Acta Dermato-Venereologica (Oslo), Vol. 28, Supplementum 20, 1948.

This volume undertakes a comprehensive treatment of the subject of joint syphilis of the delayed congenital type, as well as acquired syphilis, and syphilis of the joints and the central nervous system. The author reviews the entire field of syphilis as related to joints from the very beginning of knowledge of syphilis as a disease. In fact, he even goes into a discussion of when syphilis first appeared in Europe, and he definitely attempts to date it before the Columbian Era,—he feels it even existed in Europe in prehistoric times. The author has collected some forty-nine cases of syphilis of joints treated at Stavern, Norway, in the past fifty-two years. He presents these cases in great detail; as a matter of fact, his entire presentation of this complex subject is in laborious detail. Since the style of writing definitely follows a European pattern, the work may seem heavy to some American readers.

In addition to the historical review already mentioned, the author treats in detail each type of syphilitic manifestation in joints. One is impressed by the multiplicity of symptoms and findings which can be brought forth by the syphilitic infection. The author carefully shows that syphilis can co-exist with other diseases, not only generally, but in the joints as well. He carefully shows how syphilis can mimic many other types of infections of the joints, and he stresses in great detail the difficulty in making the diagnosis. He has personally found positive sera, not only in the blood stream but also in the exudate fluid, in the vast majority of his cases. This has not been a constant finding with all authors on the subject. The author feels that therapeutic results are more important than serological tests, for positive tests, either in the plasma or in the exudate fluid, do not necessarily mean that the arthritic involvement of the joint is due to syphilis. He also feels that specific response to antiluetic therapy is conclusive evidence that the disease is due to syphilis. Naturally, his methods of treatment do not include the use of our newer antibiotic drugs.

The author makes it clear that approximately three-fourths of all joint affliction due to syphilis, of the types being discussed, are of the late congenital type. Naturally with the routine use of the Wassermann tests, congenital syphilis is becoming a rare disease, and it has been the author's experience that all forms of syphilitic involvement of joints have been definitely on the decrease, as indeed has the disease itself. He does voice fear that the recent World War may cause an exacerbation in the occurrence of syphilis as a disease.

Gross pathological anatomy and histological changes are discussed in some detail. The roentgenographic findings are also presented and some excellent reproductions of roentgenograms are included in this monograph.

The author's summary is given in both English and French; the text is written in English. Following the text, a complete bibliography with respect to the foreign literature on this subject is included; at least a moderate amount of the American literature on the subject is given. Unfortunately, no cross index is included with this volume. This absence in so large a volume will limit the usefulness of the book for reference purposes. Nevertheless, the chapter headings may well be a sufficient guide to the student.

The author of this profound work is to be congratulated for contributing such a worth-while and comprehensive and profound book.

Orthopaedic Nursing. Frederick J. Knocke, M.D., and Lazelle S. Knocke, R.N., B.S. Philadelphia, F. A. Davis Co., 1951. $5.00.

The authors have presented the problems associated with the care of the orthopaedically handicapped patient in an interesting, well-written, complete book. There are eight contributing authors who are obviously well qualified in the special professions concerned with the treatment and rehabilitation of the orthopaedic patient within and without the hospital.

The care of the patient as a whole is repeatedly emphasized. Basic problems in orthopaedic nursing in the hospital and at home are presented in detail with excellent illustrations, a selected bibliography, and visual aids. There is a comprehensive chapter on the care of the patient with poliomyelitis.

This book will be of great value not only to those whose immediate concern is the education of nurses, but to all physicians and nurses interested in the orthopaedic patient.

Aids to Orthopaedic Surgery and Fractures, Ed. 3. I. E. Zieve, M.A. (Capetown), F.R.C.S. (Eng.). London, Bailliere, Tindall and Cox; Baltimore, The Williams and Wilkins Co., 1950.

In this pocket-size volume of 275 pages, the author has attempted the difficult task of summarizing the entire field of orthopaedic surgery and of fractures. Obviously the treatment of each topic must be brief, yet it is amazing how much information has been concentrated within the small dimensions of the book. The author has had orthopaedic experience in England, South Africa, and in Israel, where the present edition was written while he was director of surgery at the Sharon Hospital.

The fact that the book has passed through two previous editions is evidence of its popularity; it fills a need not met by the more compendious works of Watson-Jones, Bankart, McMurray, and Mercer, to all of which the author has made "free reference". The style is of necessity didactic and the reader must not expect a full exposition of conflicting views. In some sections, however, particularly that dealing with fibrositis in which he quotes the Hunterian oration of Copeman, the author has included important controversial material.

In the preface it is written, "In this edition an effort has been made to smooth out such roughnesses as inevitably occurred in the last (1944), written as it was in London during the battle of Britain". It is to be hoped that in subsequent editions a further "effort" will be made in this same direction, particularly in those sections dealing with the treatment of Perthes' disease, acromioclavicular dislocations, spondylolisthesis, and stenosing tendovaginitis. In the chapter on bone tumors mention should be made of osteoid osteoma and eosinophilic granuloma, two important entities conspicuous by their absence.

A Bibliography of Infantile Paralysis, 1789–1949; with Selected Abstracts and Annotations. Prepared under the Direction of The National Foundation for Infantile Paralysis, Inc. Edited by Morris Fishbein, M.D., and Ella M. Salmonsen, with Ludvig Hektoen, M.D. Ed. 2. Philadelphia, J. B. Lippincott Company, 1951. $16.00.

With the second edition of this bibliography, the editors and the National Foundation for Infantile Paralysis have rendered another great service to all workers in this and related fields. Emphasis is again on periodical literature and research, rather than on standard texts or pamphlets for popular information. The material is arranged chronologically, beginning with Underwood's description, in 1789, of a "debility of the lower extremities" through the outstanding work in tissue culture, epidemiology, immunology, and other aspects of the disease during the last two decades. The present edition includes work done through 1949.

A brief abstract of most of the works listed is given. There is an excellent author and subject index and, with the exception of a few minor errors in spelling, the work indicates a high degree of accuracy. The *Bibliography of Infantile Paralysis* will be found indispensable by the clinician as well as by the research scientist.

DIE DURCHBLUTUNGSSTÖRUNGEN DER GLIEDMASSEN. Dr. med. Werner Bloch. Berlin, Walter de Gruyter and Co., 1951.

This monograph is a welcome addition to the literature on the circulatory diseases of the extremities. Since it is concerned exclusively with the extremities, no attempt is made to discuss the circulatory changes in the heart or the mechanism of the higher centers of neurovascular control.

The work is divided into four parts. The first part deals with the anatomy, physiology, and pathology of the circulatory system in the extremities. Extensive reference is made to authoritative sources.

The second part is devoted to an analytical discussion of the presenting symptoms of pain, skin color and temperature, oedema, and trophic disturbances. Special methods of study and diagnosis which include oscillometry, temperature measurements, capillary microscopy, and angiography are described and critically evaluated.

The third part is given to a discussion of the various types of circulatory disturbance, whether functional, inflammatory, degenerative, or of some other nature. The individual disease forms are adequately described and the symptomatology is carefully correlated with the pathological findings.

The fourth part is concerned entirely with therapy,—conservative as well as surgical. The general plan of conservative therapy is indicated, but the consideration of the use of such drugs as dicumarol, heparin, and etamon is rather cursory. Surgical therapy, on the other hand, is given more elaborate treatment. Those measures which have fallen into disuse are mentioned merely in passing; those which are still employed are described with sufficient detail to permit their application in daily practice.

The book is profusely illustrated; many of the illustrations are in color, and numerous black-and-white photographs and photomicrographs are presented. For those who are able to read the German language, the volume is to be highly recommended.

LES XANTHOMATOSES. A. L. Froelich. Bruxelles, Les Editions Acta Medica Belgica, 1951.

This is probably the most important work on the xanthomatoses which has been published. It not only presents the author's theories with reports of personal cases, but each chapter also includes an extensive bibliography drawn from the author's thorough knowledge of the literature on the subject. This arrangement makes the book of first importance to all who wish to study the subject and of particular interest to teachers in the fields of pathology, pediatrics, neurology, orthopaedic surgery, and general medicine.

The classification adopted by the author is the one suggested by Thannhauser. The xanthomatoses are divided into two groups,—one which is accompanied by hypercholesterolaemia, and the other in which there is little or no modification of the level of the lipaemia. The first group includes not only symptomatic xanthomatosis, such as is found in the hyperlipaemia of diabetes and in liver and hypothyroid disorders, but also what is known as essential xanthomatosis, in which the hyperlipaemia cannot be related to any known cause.

Xanthomatosis appears in the course of serious cases of diabetes accompanied by acidosis.

Most of the cases of xanthomatosis observed in the course of hepatic conditions occur after obliteration of the extrahepatic ducts. In xanthomatous biliary cirrhosis, the obstruction of the biliary ducts takes place within the liver. In both of these conditions the pathogenesis of hyperlipaemia is due to the retention of a substance which provokes hyperlipaemia and which is contained in the bile.

It is unusual to see xanthomatosis develop during thyroid insufficiency; this fact indicates that, in order to justify a diagnosis of xanthomatosis, there must be not only hyperlipaemia but a marked modification of the cells in which the lipids accumulate.

In essential xanthomatosis, the hyperlipaemia is characterized by a marked increase of neutral fats. Hypercholesterolaemia is less important, and the degree of phosphataemia is less than that of cholesterolaemia. The esterification of cholesterol may be variable in the same patient. The characteristics of the condition are those of a variable hyperlipaemia, corresponding to the modifications of lipaemia which one sees in the course of essential hyperlipaemia. Hypercholesterolaemia in essential xanthomatosis is not necessarily related to decreased elimination of sterols. Indeed, in the course of complete laboratory examination, the results obtained are similar to those from tests on normal individuals.

The author discusses the relationship between the cases of disseminated xanthoma and cases of Hand-Schüller-Christian disease. He emphasizes the similarity between disseminated xanthoma and lipoid granuloma. On the basis of 350 case reports published in the literature, he presents a thorough study of the clinical symptomatology, the nature of lipaemia, and the pathological anatomy of Hand-Schüller-Christian disease.

The differential diagnosis of bone xanthomatosis has been given careful attention. According to Froelich, the bone lesions of the hand described in the course of essential xanthomatosis are the consequence of associated lesions of gout. One must also consider the possibility of the presence of the metastatic hypernephroma, of the development of spongiocytes, during the evolution of giant-cell tumors, of fibroma at the level of the metaphysis, and of bone cysts.

The bone xanthomatosis of the Snapper-Parisel type has been studied in detail from the point of view of the metabolism of lipids. The author believes that these cases belong in the same category as the disease reported by Jaffe and Lichtenstein. After analyzing the published case reports, to which he adds five cases from his personal series, he concludes that xanthomatosis of this type is the result of bone hemorrhage.

The study of the chemical composition of xanthoma allowed the author to ascertain that the cellular thesaurismosis is accompanied by esterification of the cholesterol and that necrosis of the cells determines its free crystallization. Froelich attempts in his book to establish the meaning of the spongiocytic transformation of the cell elements. This may be the consequence of several factors: the anoxaemia of fat cells, the resorption by reticulo-endothelial cells of necrosed inflammatory cells or of remnants of local hemorrhages. Froelich sees in this an important factor in the spongiocytic transformation of certain parts of the granuloma of Hand-Schüller-Christian disease. As a matter of fact, certain tumors of the mesenchyme show, in association with hemorrhages, a chemical composition similar to that of lipoid granuloma. The work concludes with a general study on lipoidosis.

ACKNOWLEDGMENTS

The Journal wishes to acknowledge receipt of the following publications which have been sent to the Editorial Department:

Acta Chirurgiae Orthopaedicae et Traumatologiae Čechoslovaca (Praha), **18:** Num. 5–7, 1951.
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Acta Societatis Medicorum Upsaliensis (Uppsala), **56:** Nos. 3–4, 1951.
Anales del Servicio de Traumatologia del Dr. Lopez-Trigo (Valencia), **6:** Núm. 1, 1951.
Archiva Medica Belgica (Bruxelles), **6:** Fasc. 1, 2, 3, 1951.
Archivos de la Sociedad de Cirujanos de Chile (Santiago de Chile), **3:** Núm. 2, 1951; Numero Extrordinario, Segundo Congresso, 1951.
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Boletín del Instituto de Patología Médica (Madrid), **6:** Núms. 7, 8, 1951.
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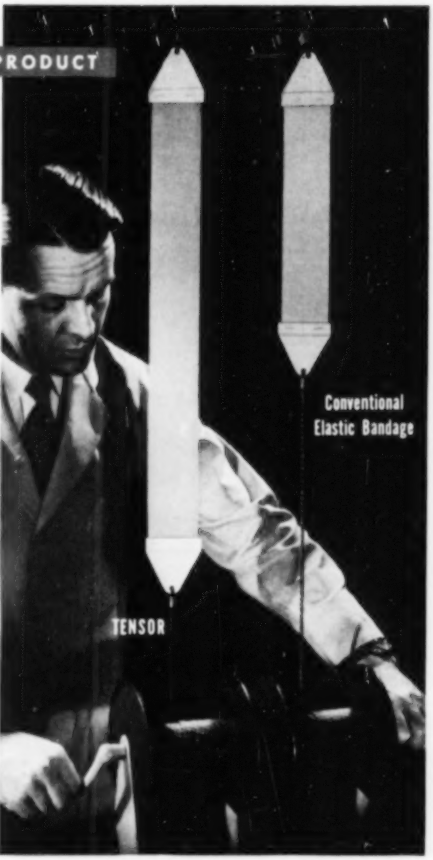

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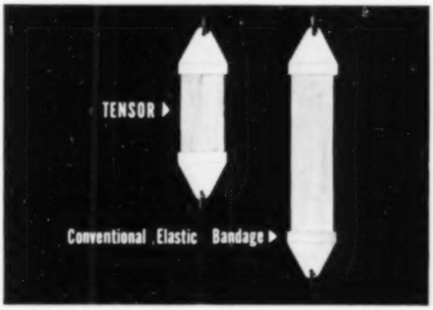

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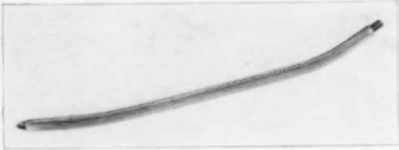
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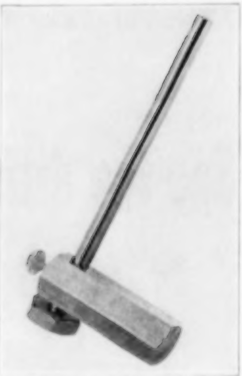
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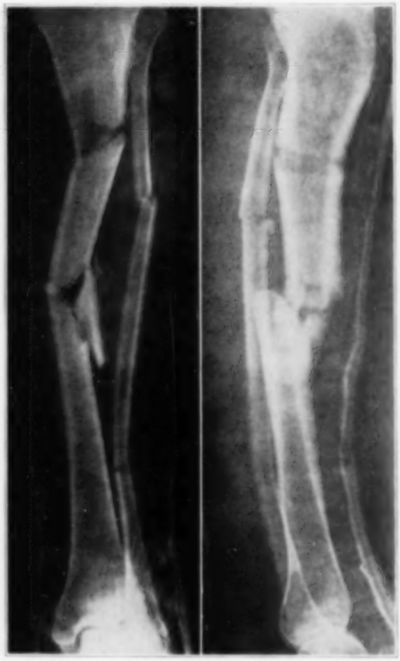
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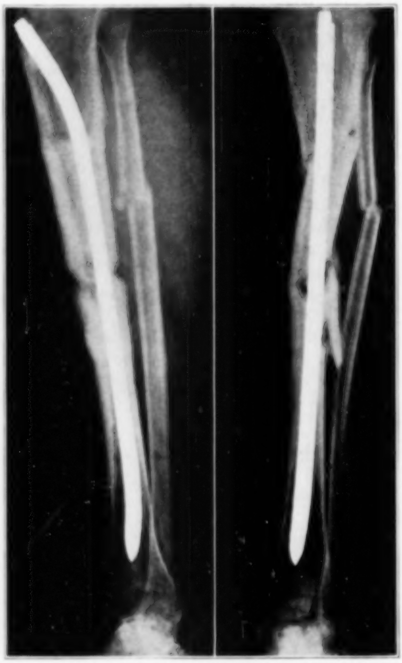
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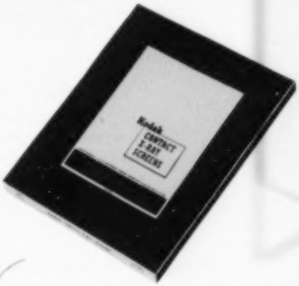

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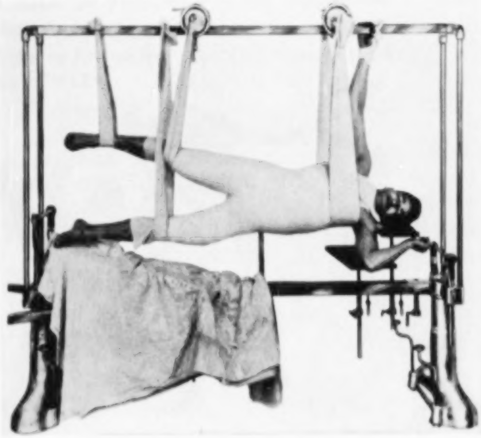

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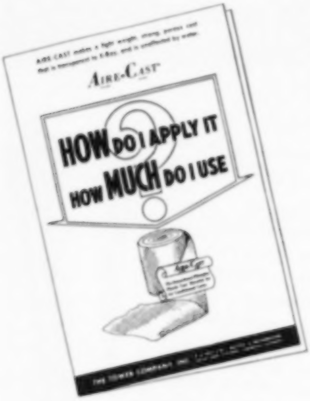

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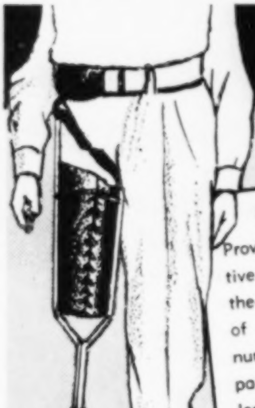

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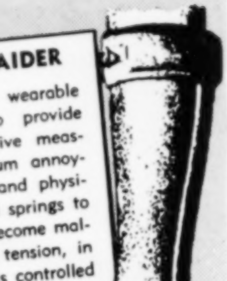

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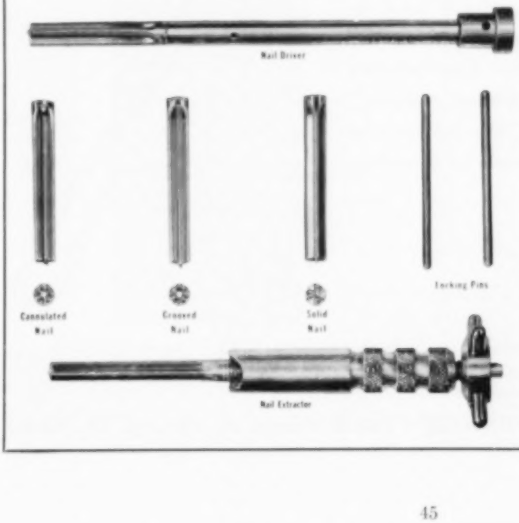

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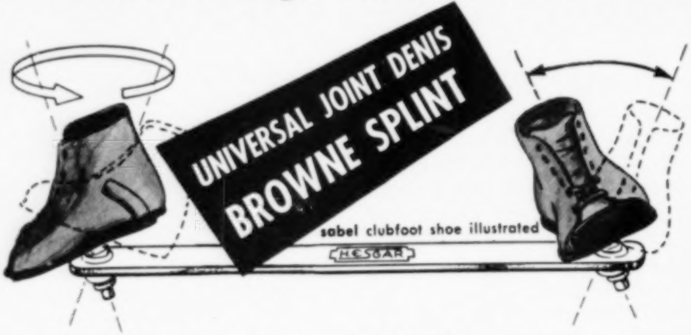

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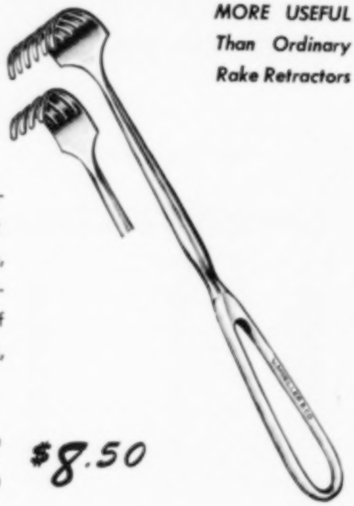

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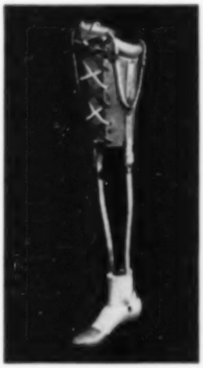

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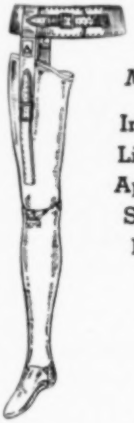

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